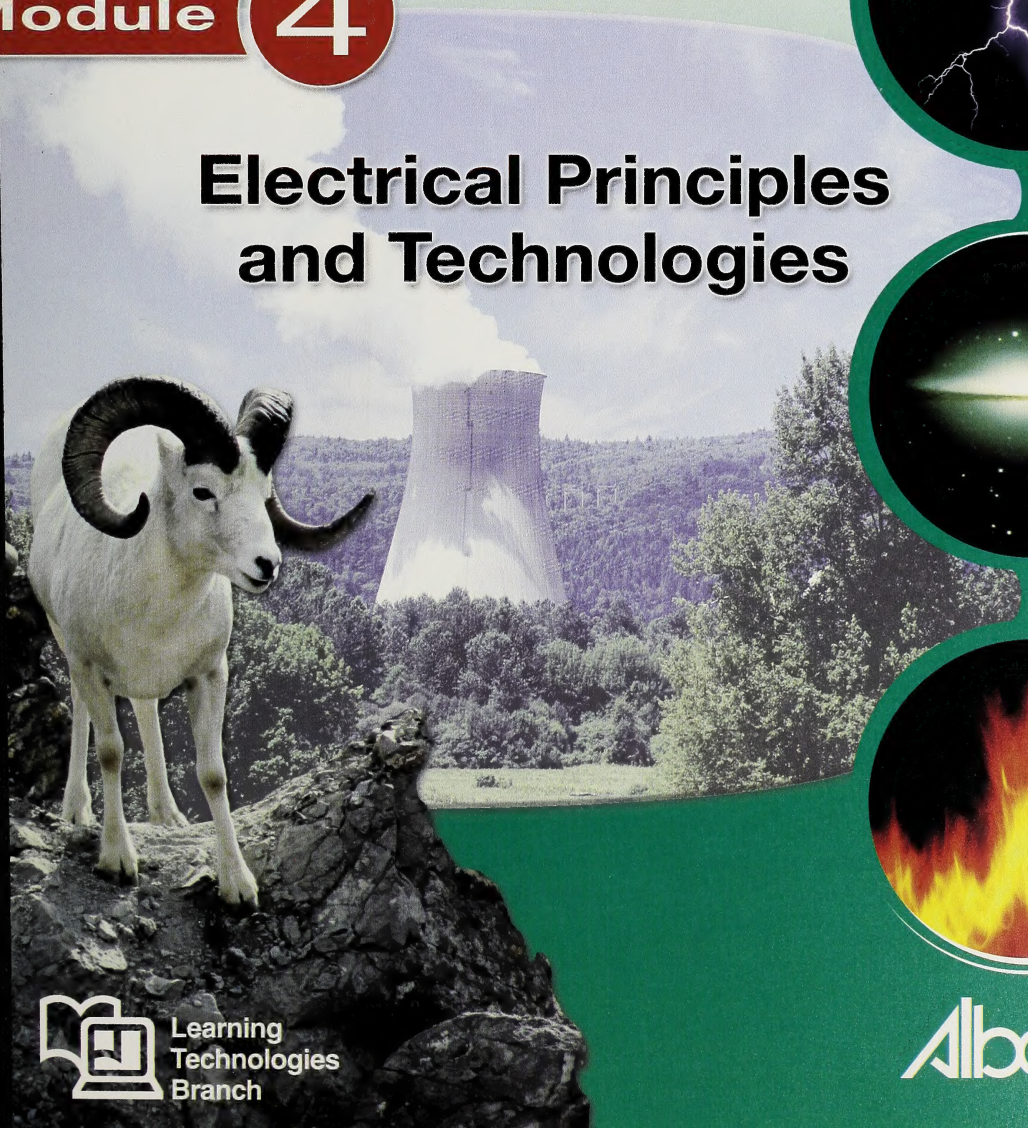
SCIENCE 9

Module 4



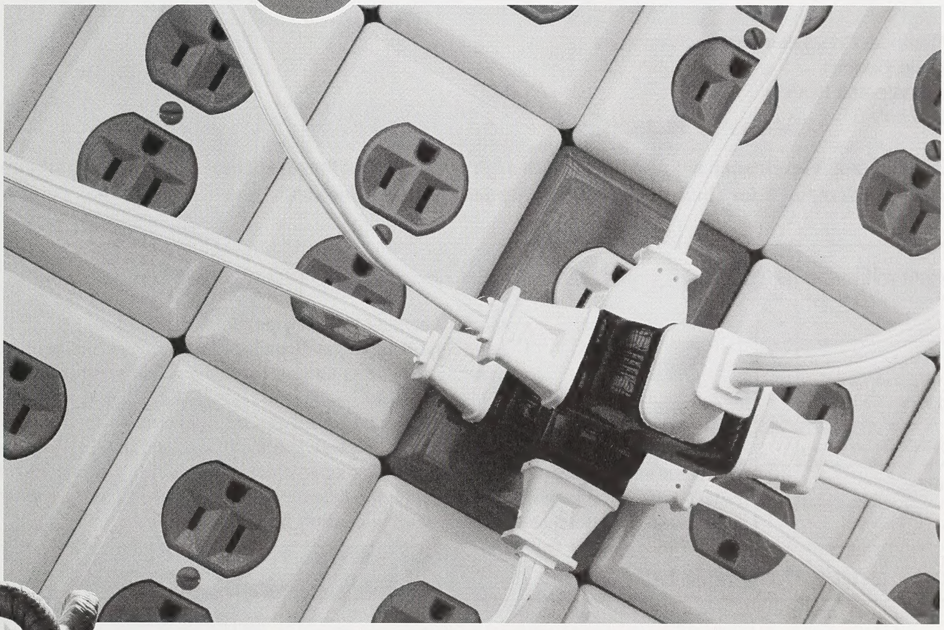
Electrical Principles and Technologies

Learning Technologies Branch

Alberta LEARNING

SCIENCE 9

Module 4 Electrical Principles and Technologies



Science 9
Module 4: Electrical Principles and Technologies
Student Module Booklet
Learning Technologies Branch
ISBN 0-7741-2592-6

The Learning Technologies Branch acknowledges with appreciation the Alberta Distance Learning Centre and Pembina Hills Regional Division No. 7 for their review of this Student Module Booklet.

This document is intended for	
Students	✓
Teachers	✓
Administrators	
Home Instructors	
General Public	
Other	

You may find the following Internet sites useful:

- Alberta Learning, **http://www.learning.gov.ab.ca**
- Learning Technologies Branch, **http://www.learning.gov.ab.ca/ltb**
- Learning Resources Centre, **http://www.lrc.learning.gov.ab.ca**

The use of the Internet is optional. Exploring the electronic information superhighway can be educational and entertaining. However, be aware that these computer networks are not censored. Students may unintentionally or purposely find articles on the Internet that may be offensive or inappropriate. As well, the sources of information are not always cited and the content may not be accurate. Therefore, students may wish to confirm facts with a second source.

WELCOME to Science 9!

It is recommended that you work through the modules in order because the concepts and skills introduced in one module will be reinforced, extended, and applied in later modules.

Module 1 Biological Diversity

Module 2 Matter and Chemical Change

Module 3 Environmental Chemistry

Module 4 Electrical Principles and Technologies

Module 5 Space Exploration

Module 1 contains general information about the course components, additional resources, icons, assessment, and strategies for completing your work. If you do not have access to Module 1, contact your teacher to obtain this important information.

Contents

Resources 6

Before You Begin 6

Icons 7

Module Overview 8

Assessment 9

Planning Ahead 10

Section 1: The Basics of Electricity 11

Lesson 1: Electric Charges 12

Lesson 2: Electricity Within a Circuit 17

Lesson 3: Resisting the Movement of Charge 25

Lesson 4: Wrap-up 32

Section 1 Conclusion 33

Section 2: Energy Conversions 34

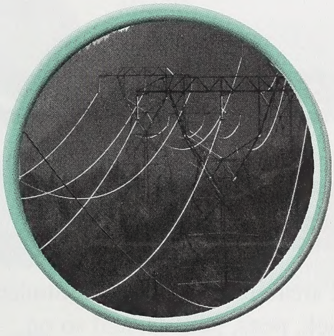
Lesson 1: The Energy Connection 35

Lesson 2: Portable Power 39

Lesson 3: Wrap-up 45

Section 2 Conclusion 46

Section 3: Electricity Production, Distribution, and Use 47



Lesson 1: Generators and Motors 48

Lesson 2: Electricity in the Home 54

Lesson 3: Electricity Production and the Environment 63

Lesson 4: Wrap-up 67

Section 3 Conclusion 68

Module Summary 69

Module Review 69

Appendix 70

Glossary 71

Suggested Answers 75

Image Credits 109

Resources

Textbook

To complete the course, you need the textbook *ScienceFocus 9*.

Multimedia

Attached to Student Module Booklets in this course are CDs titled *Science 9 Multimedia* and *Science 9 Multimedia*: *Astronomy*. These CDs contain multimedia segments designed to help you better understand particular concepts presented in this course. Ask your teacher or home instructor if you need help using these CDs.

Materials and Apparatus

A list of materials and apparatus is given on the Planning Ahead page of each Student Module Booklet. These items are needed to complete the module. Some of the materials and apparatus may be provided at your local school lab. If you don't have access to a school lab, you will need to get the loan kit. Talk to your teacher for more information.

Before You Begin

Organize your materials and work area before you begin: Student Module Booklet, textbook, notebook, pens, pencils, and so on. Make sure you have a quiet area in which to work, away from distractions.

Because response lines are not provided in the Student Module Booklet, you'll need a looseleaf binder or notebook to respond to questions and complete charts. It's important to keep your lined paper handy as you work through the material and to keep your responses together in a notebook or binder for review purposes later.

Refer to the Planning Ahead page for directions on what you need to do before you start this module.

Good luck!

Icons

This is one of five Student Module Booklets for Science 9. As you progress through this module, you will meet several icons.

Do Ahead

Some preparation must be started well ahead of the activity or investigation. E.g., start the seedlings for the investigation in Lesson 3.

Teacher or Home Instructor

The teacher or home instructor should be contacted for help, approval of some procedure, or checking answers.

Assignment Booklet

Work needs to be done in an Assignment Booklet.

Safety

You must be very careful when you see this symbol.

Textbook

A reference is made to *ScienceFocus 9*, the student textbook for this distance learning course.

Internet

This is a reference to the Internet. **Note:** Any Internet website given is subject to change.

Multimedia

This is a reference to the *Science 9 Multimedia* CDs.

Computer

You will need to work with a computer when you see this symbol.

Module Overview

Have you ever experienced a power outage? That's what happens when electricity stops flowing in the power lines to your community or home. Can you imagine your world without any electricity? Just think about how many different electrical devices you use in an average day! How would you cope if they weren't available? At the flick of a switch, electricity instantly lights a lamp, turns on a CD player, or heats your food. Have you ever wondered how electricity can do so many things?

Section 1
The Basics of Electricity

Section 2
Energy Conversions

Section 3
Electricity Production, Distribution, and Use

Electricity is useful, but it can also be dangerous. Electricity must be controlled in order to do the things it should.

In this module you will investigate how electricity is controlled, used, produced, and distributed. You will also examine its environmental impacts.

Check out pages 262 to 265 of the textbook. You'll see what's coming up in this module.

Assessment

The booklet you are presently reading is the Student Module Booklet. It will show you, step by step, how to advance through Module 4: Electrical Principles and Technologies.

This module, Electrical Principles and Technologies, has three sections. Within each section your work is grouped into lessons. Within the lessons there are readings, investigations, activities, and questions for you to do. By completing these lessons you will discover scientific concepts and skills, develop a positive attitude toward science, and practise or apply what you have learned.

Suggested answers in the Appendix of this Student Module Booklet will provide you with immediate feedback on the answers to questions in the lesson. Your teacher or home instructor will also provide you with feedback on your progress through the module.

At several points in this module you will be directed to an accompanying Assignment Booklet. Your grading in this module is based on the assignments you submit for assessment. In this module you are expected to complete three section assignments and a Final Module Assignment.

The mark distribution is as follows:

Assignment Booklet 4A	
Section 1 Assignment	37 marks
Section 2 Assignment	36 marks
Assignment Booklet 4B	
Section 3 Assignment	33 marks
Final Module Assignment	49 marks
TOTAL	155 marks

Planning Ahead

Here is a list of materials and apparatus you will need to complete this module.

Section 1

- ❑ a 3.7 V bulb
- ❑ a knife switch
- ❑ two, 2.5 V bulbs
- ❑ two battery (cell) holders
- ❑ two bulb sockets
- ❑ two fresh D-cells
- ❑ three, 3.7 V bulbs and three bulb holders
- ❑ eight, 15 cm wires with stripped ends
- ❑ 12 alligator clips
- ❑ a multimeter
- ❑ paper towels
- ❑ tape

Section 2

- ❑ two, 3.7 V bulbs and holders
- ❑ two, 15 cm wires with stripped ends
- ❑ three battery (cell) holders
- ❑ three fresh D-cells
- ❑ heavy-duty aluminum foil
- ❑ a multimeter
- ❑ paper towels
- ❑ a saturated salt solution
- ❑ scissors
- ❑ a steel wool pad
- ❑ tape
- ❑ various coins (pennies, nickels, dimes, and so on)

Section 3

- ❑ one disposable cup
- ❑ a fresh D-cell
- ❑ a rectangular or round ceramic magnet (about 1 cm by 3 cm)
- ❑ a wide rubber band
- ❑ two large paper clips
- ❑ a 5 m insulated 26 gauge copper wire
- ❑ 60 cm of enamel coated magnet wire
- ❑ a broom handle
- ❑ a bar magnet
- ❑ a cardboard tube
- ❑ fine sandpaper or steel wool
- ❑ a multimeter
- ❑ tape

If you have access to the Internet, you may want to check out some of the links for this module ahead of time. Go to the following site:

http://www.mcgrawhill.ca/school/booksites/sciencefocus+9/student+resources/toc/index.php

Get a head start on batteries, electric motors, circuit breakers, and more by going to this site:

http://electronics.howstuffworks.com/channel.htm?ch=electronics&sub=sub-building-blocks

Section 1

The Basics of Electricity

There's nothing like spending time listening to your favourite music.

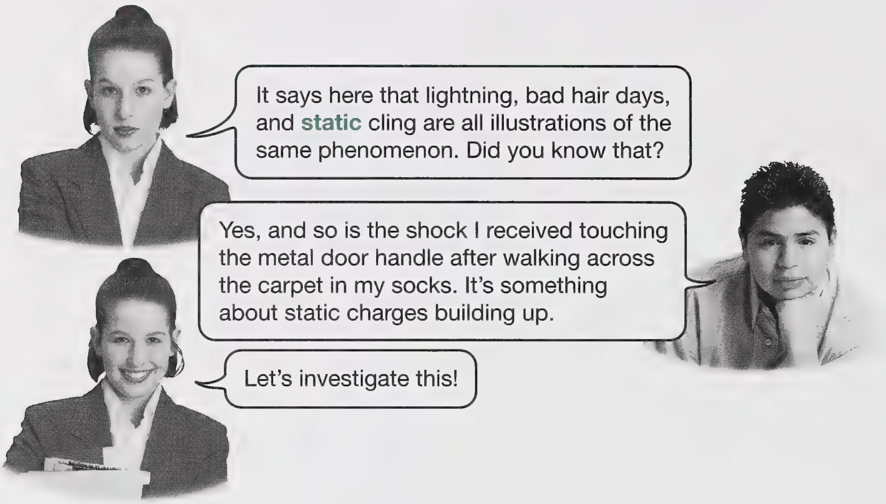
The current powering your CD player consists of a moving electric charge. But a moving electric charge can also be a bolt of lightning that knocks down a tree. One moving charge does what you want; the other is a violent, destructive phenomenon. What scientific principles tie these two phenomena together? What technologies have been developed to tame the awesome power of electric energy?

Both phenomena involve moving an electric charge. In a CD player the electric charge moves along paths that make up a circuit. The electric charge in a lightning strike hardly follows a defined path—it takes a zigzag route through the air from one place to another location. Viewing the role of a moving electric charge in both a CD player and a lightning strike will show the close connection between these phenomena.

In this section you will study electricity as a movement of electric charge and you will discover how and why an electric charge moves. You will see how a moving electric charge can be harnessed in electric circuits. You will also find that resistance to an electric current is both a hindrance and a help.

Lesson 1: Electric Charges

static: *without movement; stationary*



Turn to page 266 of the textbook and read the topic introduction.

The energy of moving charges powers electrical devices. The nature of electrical charges can be studied by rubbing certain materials. This is done in the next activity.

You don't need to physically do the investigation—a student observation table is provided. Use the table to draw some conclusions about the interactions of charged objects.

Find Out Activity Charge It

Read through the activity on page 266 of the textbook.

Study the steps of "Procedure." Note that the strips are charged through rubbing. The strips are made of different materials, and they get charged differently based on their make-up.

One group of students found that the balanced strips behaved as indicated in the following observation table.

Trial	Strip Balanced on the Watch Glass	Hand-held Strip	Behaviour of Balanced Strip (Attracts, Repels, Nothing)
1	uncharged acetate	uncharged acetate	nothing
2	uncharged acetate	charged acetate	attracts
3	charged acetate	charged acetate	repels
4	charged acetate	uncharged vinyl	attracts
5	charged acetate	charged vinyl	attracts
6	charged vinyl	charged vinyl	repels
7	uncharged vinyl	uncharged vinyl	nothing

1. Answer questions 1 to 3 from "What Did You Find Out?" on page 267.

Compare your responses with those in the Appendix on page 75.

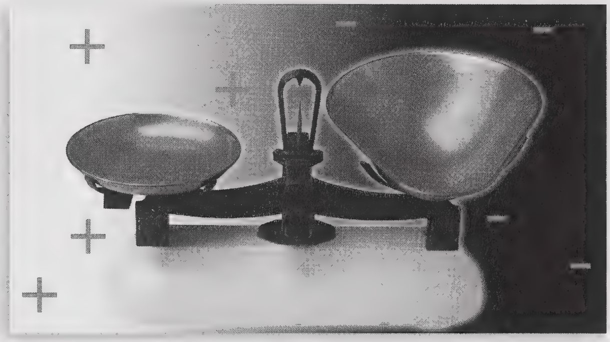
Going Further

Have you read "Looking Ahead" on page 265 of the textbook? It gets you started on your own technological invention! You can design, build, test, troubleshoot, and improve an electrical device as your final project for this module.

These "Going Further" sections are for those of you who want to do extra in-depth work. There are lots of interesting topics to work on.

Producing a Charge Imbalance

Charged objects attract or repel other charged objects. They always attract neutral objects. The early experimenters theorized that electric charges come in two types—positive and negative. Any object carries many little electric charges. A neutral object is one that has a balance of positive and negative electric charges. If an object has more positive charges than negative charges—or the other way around—the object has an imbalance of charges. Such an imbalance makes the object electrically charged.



Find out what leads to unbalanced charges in the first place.

Turn to pages 267 and 268 of the textbook and read "Producing Charges."

The modern view is that every atom of a substance has electrons moving around the atom's positively charged nucleus. Some electrons can escape from "their" atoms and even move from one object to another. Charge imbalance is due to such a movement of electrons—not protons. When you produce a charge on an object by, for example, rubbing a strip of plastic with a paper towel, electrons migrate from one of the interacting materials to the other. Electrons are not lost. They are merely transferred. This transfer causes a charge imbalance on both interacting objects—they both become charged.

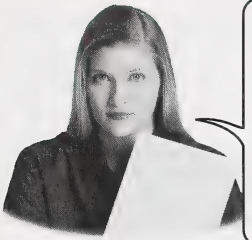
Turn to page 268 of the textbook and read "Making Sense of Electric Charges."

2. Predict the charge (positive or negative) on a previously neutral material that has lost electrons or gained electrons.

3. What did Benjamin Franklin call the charge left on amber when it was rubbed with fur? What did he call the charge left on the fur?

Compare your responses with those in the Appendix on page 75.

Conductors and Insulators



Suppose your father asks you to remove two hot pans from the stove. One of the pans has a plastic handle, while the other has a metal handle. How would you remove them? Would you test each handle temperature before grasping it? Would you use an oven mitt for both pans? What knowledge guides your decision?

That's pretty straightforward. Metals conduct heat better than non-metals. So, the metal handle is probably too hot to handle with my bare hands. The plastic handle is cool enough to touch.

I agree it's quite elementary. But the example relates to electrical conductivity. Along with differences in thermal conductivity, there are differences among materials in their abilities to conduct electricity. Based on this property, scientists classify materials as conductors, insulators, semiconductors, and superconductors.

Turn to page 269 of the textbook. Read "Conductors, Insulators, and In-Between."

4. Refer back to "Find Out Activity: Charge It," which you looked at earlier in this lesson.

   a. Explain why glass is used to support both the acetate strips and the vinyl strips.

   b. Classify acetate and vinyl as conductors or insulators. Explain your answer.

5. Refer to "Table 4.1" on page 269. Note that water is listed as both a "Fair Conductor" and an "Insulator." Why?

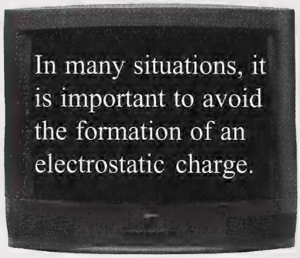
6. Do the "Pause and Reflect."

7. Suggest why superconductors are not used in household circuits.

Compare your responses with those in the Appendix on page 75.

Discharging and Preventing Charge Buildup

Have you ever noticed that dust seems to stick to a TV screen? The screen has to be cleaned often. Dust is attracted to the screen because the screen becomes electrically charged.



Turn to page 270 of the textbook and read “Neutralizing Unbalanced Charges” and “Preventing Electrostatic Buildup.”

8. What happens when you “ground” an object?

9. Explain why an electrostatic charge buildup can be troublesome even when no electric discharge or spark occurs.

Compare your responses with those in the Appendix on page 76.

Going Further

The news about electrostatics is not all bad. In fact, many useful technologies apply to electrostatics. Some, like the photocopier, are quite familiar to you. In “Find Out Activity: Putting Electrostatics to Work,” you will research useful applications of electrostatics. Refer to page 271 of the textbook.

10. Turn to page 271 of the textbook and do question 1 of “Topic 1 Review.”

Compare your response with the one in the Appendix on page 76.

Looking Back

In this lesson you studied the nature of electric charge and the laws of charges. You found that materials are classified into conductors, superconductors, semiconductors, and insulators. A variety of implications and applications of electrostatics were studied.

Turn to Assignment Booklet 4A. Complete questions 1 to 3 from Section 1.

Lesson 2: Electricity Within a Circuit

Did you plug in an appliance this morning? Maybe it was a hair dryer, a toaster, or an electric frying pan. Or maybe you used an electrical appliance that was already plugged in, such as a microwave oven or an electric range. All these appliances use electricity that flows along a conducting path called an *electric circuit*.

In Lesson 1 you studied static electricity—a charge buildup that remains in one area waiting to be discharged. In current electricity, these electric charges move along a circuit. The electric charges are electrons.

Turn to page 272 of the textbook and read the opening paragraph.

In this lesson you will study current electricity where electrons move in one direction through a circuit.

You'll start by building your own simple circuits.

Find Out Activity Light That Bulb?

Refer to the activity on page 272 in your textbook.

Follow the steps of "Procedure."

Don't make a circuit without a light bulb. With the circuit running directly from one side of a battery to the other, wires overheat. Use at most two D-cells. More cells can cause the bulb to burn out and the wires to overheat.

Be sure you are using a 3.7 V bulb. The 2.5 V light bulbs that are also included in your loan kit may burn out with certain circuit arrangements. You may use tape instead of alligator clamps to hold wires in place.

1. Answer the questions from "What Did You Find Out?" and "Extension."

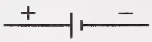
Check your answers with your teacher or home instructor.

When you're travelling, it helps to see roads represented on a map.

To understand a circuit, it helps to see it in a kind of map called a circuit diagram. All circuits—even complex ones—have just four basic elements. By using symbols for these elements, a circuit diagram can be drawn. Such a diagram will show just the essence of the circuit.

Turn to page 273 of the textbook and read "Circuit Elements and Diagrams" to find out how to draw circuit diagrams. Also read "Word Connect."

2. Match each symbol to the basic circuit component that it is part of. Write down the component letters in the answer blanks to the left of each symbol.

___ **a.** 

___ **b.** ————

___ **c.** 

___ **d.** 

___ **e.** 

___ **f.** 

A. conductor

B. control

C. load

D. source

3. How do a cell and a battery differ?

4. Use the circuit diagram criteria on the bottom of page 273 of the textbook to draw a circuit containing

   a. a 2-cell battery, a switch, and a light bulb

   b. a 3-cell battery, a switch, a light bulb, and a resistor

   c. a 4-cell battery, a switch that will open one circuit as it closes another, and two light bulbs—one will shut off when the other turns on

Compare your responses with those in the Appendix on page 77.

Measuring Electrical Current

Have you seen the Horseshoe Falls on the Niagara River? Or the American Falls? The flow rate of the Niagara River varies with the season, but its average flow rate is 360 million litres per second! Much of the water is diverted upstream from the falls for hydroelectric power. Some water goes over the American Falls.

Yet, during an average summer day, you will see plenty of water going down the Horseshoe Falls. The thunderous sound of Horseshoe Falls is due to a flow rate of almost 180 million litres per second!

quantitative data: data that consists of numbers and units of measurement

It's useful to record the number of litres of water that flow past a ridge or point on a river during a certain time interval. With this information you can express the flow rate of rivers as **quantitative data**. Electric current flow can also be expressed as quantitative data, but the units "litres per second" are not appropriate. In the next reading, find out what units are used for electric current flow.

Turn to page 274 of the textbook and read "Measuring Current." Pay attention to the symbol used to represent electric current, the standard unit for electric current, and the instruments used to measure electric current.

DID YOU KNOW?

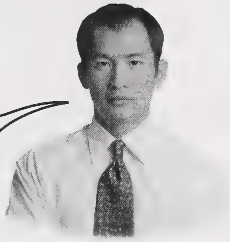
The unit *ampere* is named after French scientist and mathematician André-Marie Ampère (1775–1836).

5. What moves through a conductor to create an electric current?

6. Use the words *ammeter* and *galvanometer* to complete the following statements.

   Both a(n) ____________ and a(n) ____________ are meters used to measure electrical current. The ____________ is used to measure strong currents, whereas the ____________ is used to measure currents too small for the ____________.

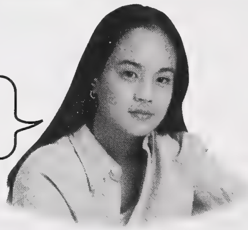
To keep new information straight about currents and circuits, start a table titled "Symbols, Units, and Formulas" in your notebook. Refer to "Pause and Reflect" on page 274. Add a fourth column, "Formula," to your table. Include enough rows for a total of ten different quantities. Add to this table as you move through Module 4.



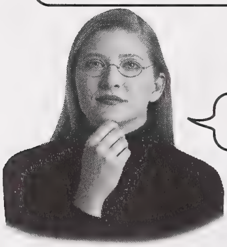
Compare your responses with those in the Appendix on page 77.

Measuring Voltage

Have you seen a sign warning trespassers about high voltage? Large electrical transformers surrounded by chain-link fences likely have warnings such as this. Even if a gate is left open, it's a good idea to stay out. High voltage can kill.



What is voltage? I know things you plug into an electrical outlet run on 110 volts. But what is a volt?



Good questions. The next reading will address your questions.

Turn to page 275 of the textbook and read "Measuring Voltage." Add new quantities to your notebook after referring to "Pause and Reflect."

7. The "push" that moves electrons along a circuit is due to potential differences of points in the circuit.

   a. What is the standard unit for potential difference?
   b. Who is this unit named after?

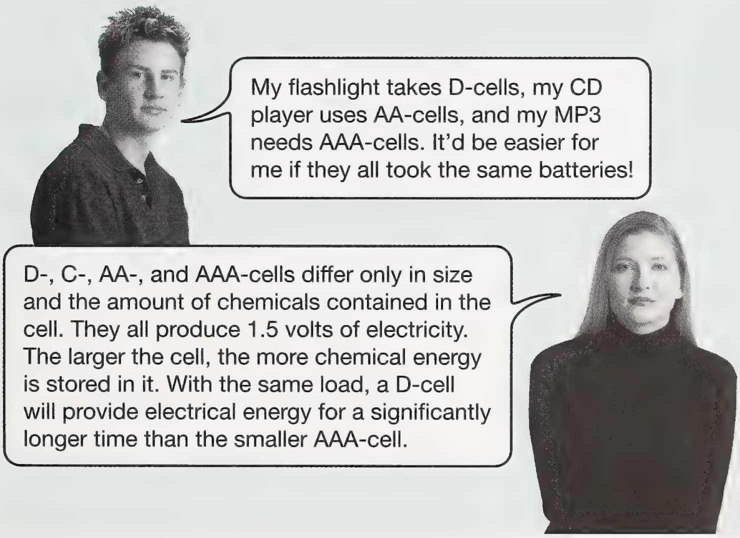
A multimeter is an instrument that can function as an ammeter or a voltmeter. You will likely have access to a multimeter to make current or voltage readings.

8. Draw a schematic diagram for the hookup shown in "Figure 4.13." Think of the multimeter operating as a voltmeter. Use the symbol for voltmeter to represent the multimeter in the circuit.

   It may help you to look at the circuit diagram in "Figure 4.16" on page 281 of the textbook. Identify the symbol for voltmeter.

Compare your responses with those in the Appendix on page 77.

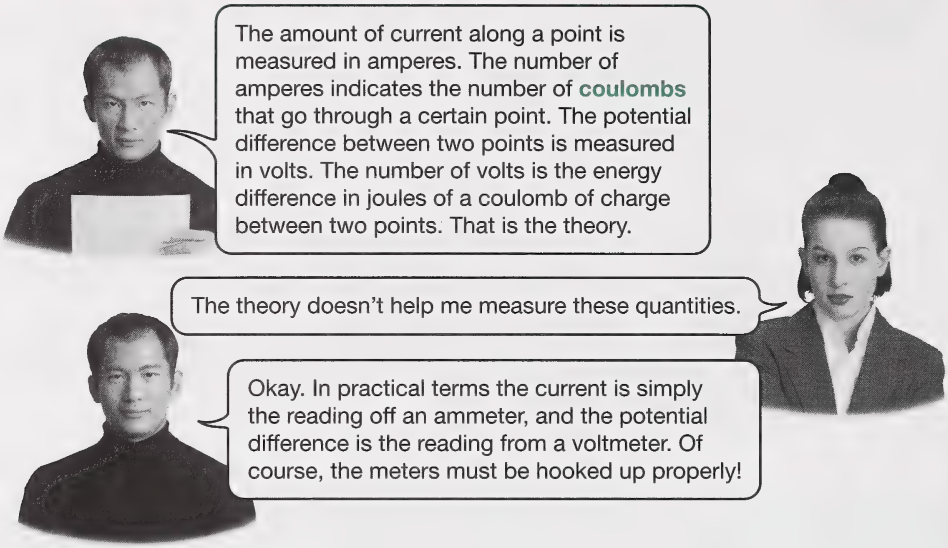
DID YOU KNOW?



Connecting Meters to Measure Current or Voltage

coulomb: *the SI standard unit of charge*

One coulomb is the charge of 6.25×10^{18} electrons.



Turn to pages 488 to 490 of the textbook. Read "Skill Focus 14: Connecting and Reading Ammeters and Voltmeters."

Practise connecting ammeters and voltmeters on your computer screen. Place the *Science 9 Multimedia* CD in your computer. On the main menu screen, select "Ammeters and Voltmeters" and work through this resource.

9. Match the meters on the right with a description on the left. Write the letters from A to C in the answer blanks.

___ **a.**	connected to two points in the circuit	A. ammeter
___ **b.**	measures a quantity at a point in the circuit	B. voltmeter
___ **c.**	requires one additional wire for hook up	C. voltmeter and ammeter
___ **d.**	requires two additional wires for hook up	
___ **e.**	must be connected with proper polarity	

10. See “Instant Practice” on page 490 of the textbook. Determine the values indicated by the following.

Be sure to first check “Reading Meters,” which starts on page 489.

a. “Figure 6A”
b. “Figure 6B”
c. “Figure 6C”
d. “Figure 6D”

Compare your responses with those in the Appendix on page 78.

Not all meters are the same. Before using an instrument to measure current characteristics, read the manual that comes with it. You must know which settings to use and which scale to read. Keep in mind that to have a meaningful reading, you have to correctly connect the meter.

A multimeter can be easily damaged if it’s used incorrectly!

NEVER TEST A HOUSEHOLD CIRCUIT OR AN ELECTRICAL DEVICE! Testing could result in serious injury or death!

In the following investigation you will construct a simple electric circuit. You will then use an instrument to measure both the current and the voltage.

Investigation 4A Current and Voltage

Refer to the “Inquiry Investigation” on pages 276 and 277 of your textbook.

Part A: Measuring Current

Read “Question” and “Prediction.” Write your prediction in your notebook.

11. Explain why you are using a single 3.7 V bulb in this circuit rather than a single 2.5 V bulb.

Carry out the steps of “Procedure.”

12. Answer questions 1 to 3 from “Analyze” and questions 4 and 5 of “Conclude and Apply.”

Compare your responses with those in the Appendix on page 78.

Part B: Measuring Voltage

Read "Question" and "Prediction." Write your prediction in your notebook.

Carry out the steps of "Procedure."

13. Answer questions 1 to 4 of "Analyze" and question 5 from "Conclude and Apply."

Compare your responses with those in the Appendix on page 79.

end of investigation

Water systems are often used as models of electrical circuits. The comparison to water systems is made so that electrical circuits are easier to understand. The next reading asks you to visualize an electrical circuit as a water system.

Turn to page 278 of the textbook and read "Rivers of Electricity."

14. Refer to "Figure 4.14." Using digits *1* to *4*, identify the following points in the diagram.

    a. highest energy **b.** control **c.** load

Compare your responses with those in the Appendix on page 79.

15. To test your understanding of the concepts in this lesson, answer questions 2 and 3 from "Topic 2 Review" on page 278 of your textbook.

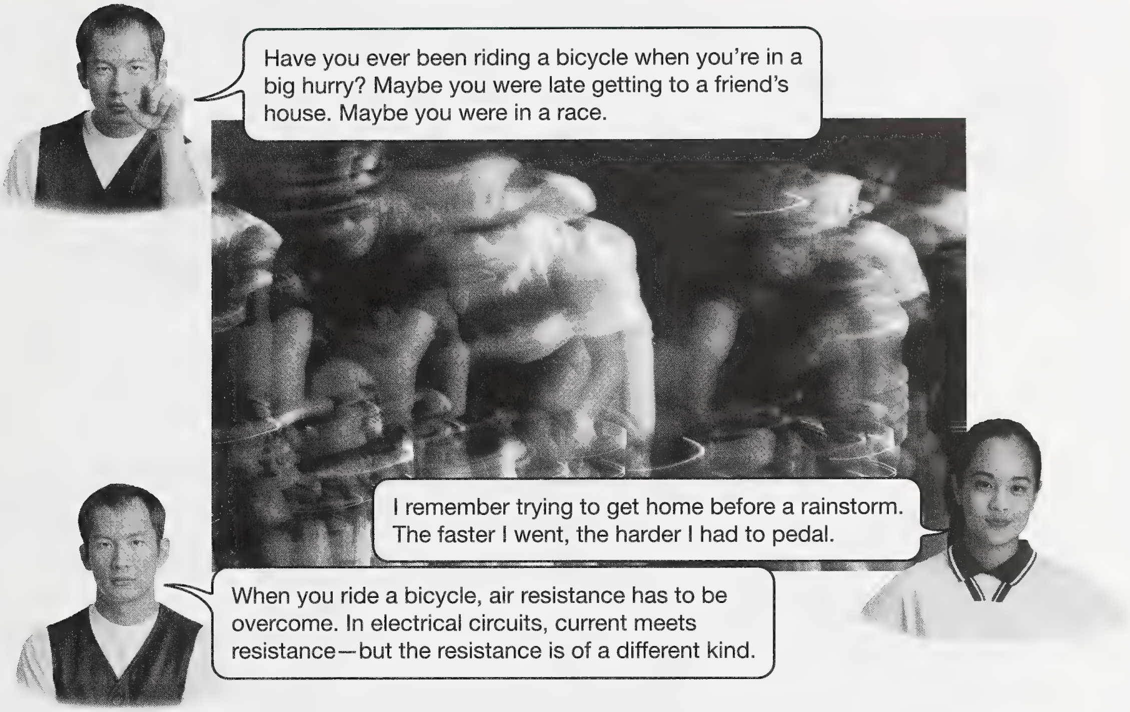
Compare your responses with those in the Appendix on page 79.

Looking Back

In this lesson you studied the four basic parts of all electrical circuits and practised drawing simple circuit diagrams. You then built two simple electric circuits. You used an ammeter to measure current and a voltmeter to measure voltage at various points within the circuits. These measurements allowed you to study the effect of loads on current and voltage within a circuit.

Turn to Assignment Booklet 4A. Complete questions 4 to 6 from Section 1.

Lesson 3: Resisting the Movement of Charge



You can visualize resistance to electricity in this way. Imagine a hallway with Velcro patches on the walls and Velcro-covered obstacles on the floor. You're in a Velcro suit, and you need to pass through this hallway. The ease in which you get through this hallway will depend on how often you get "attached." If there are only a few Velcro patches on the walls and few obstacles, you will move through the hallway easier than if there are many patches and obstacles.

The "Velcro" attraction is similar to the attraction between individual atoms and electrons in solids. If the atoms of a material strongly cling to electrons, the material has high resistance. If they cling weakly, the material has low resistance.

Turn to page 279 of the textbook. Read the topic introduction.

1. What form(s) of energy does a light bulb filament convert electrical energy into?

2. Complete the following sentences.

   A good conductor has ____________ resistance. Poor conductors have ____________ resistance. An ____________ is the standard unit for resistance. Resistance is measured with an ____________.

In the next activity you can investigate the effects of changing resistance in a circuit.

Find Out Activity Resistance Roadblock

Refer to the activity on page 280 of your textbook.

Compare the circuit diagram to the picture of the circuit. Note that wire made from Nichrome—an alloy of iron and chromium with a nickel base—has a higher resistance to electron flow than copper wire does. The longer the length of Nichrome included in the circuit's path, the greater the resistance in the circuit.

Complete step 1 of "Procedure."

If you have access to Nichrome wire, carry out the remaining steps of "Procedure." If not, use the data in the following data table.

Current and Bulb Brightness

Location of Lead #2 on Nichrome	Current (mA)		Bulb Brightness	
	Predicted (Low, Medium, High)	Actual	Predicted (Dim, Medium, Bright)	Actual
A		520		bright
B		460		medium
C		360		dim

3. Answer questions 1 to 3 of "What Did You Find Out?" and questions 1 and 2 from "Extension."

Compare your responses with those in the Appendix on page 80.

Turn to page 281 of the textbook and read "Calculating Resistance."

Refer to "Pause and Reflect" on page 281. Add resistance and formulas for resistance, voltage, and current to your "Symbols, Units, and Formulas" table. This table is in your Science Log.

4. State Ohm's law in words and in an algebraic equation. Make resistance the subject of the equation. Repeat the equation with voltage as the subject.

The "Model Problem" on page 282 of your textbook illustrates the GRASP method of problem solving—**G**iven, **R**equired, **A**nalysis, **S**olution, and **P**araphrase. Use the GRASP method for computational problems.

5. Do "Practice Problems" 1 to 3 on page 282.

Compare your responses with those in the Appendix on page 80.

resistor: *a device that has electrical resistance and that is used in an electric circuit for current and voltage control*

You have seen that resistance is used to convert electricity to light and heat. Resistance is also used to control the flow of electricity in circuits.

The next time you dim the lights, you're using a variable **resistor**.

Turn to page 283 of the textbook and read "Resistors" and "Variable Resistors."

6. Identify an application for a thermistor and a rheostat.

Compare your response with the one in the Appendix on page 82.

Next, you will investigate relationships between current, resistance, and voltage.

Refer to the "Inquiry Investigation" on pages 284 and 285 of your textbook.

7. Write your hypothesis in your notebook.

When following the steps of "Procedure," a student named Juri collected the following data.

Electric Current, Voltage, and Resistance

Resistor	Voltage (V)	Measured Current (mA)	Calculated Resistance (Ω)
Resistor 1 R = 30 Ω	1.0	32	
	2.0	68	
	3.0	100	
	4.0	130	
	6.0	200	
Resistor 2 R = 60 Ω	1.0	16	
	2.0	34	
	3.0	50	
	4.0	67	
	6.0	101	

You may find a computer spreadsheet to be helpful when you complete the "Calculated Resistance" column. Remember to convert mA to A.

Use the data Juri collected to answer the following questions.

8. Complete questions 1 and 2 of "Analyze" and questions 3, 4, and 6 of "Conclude and Apply."

If you have the necessary equipment you may want to actually carry out the steps of "Procedure." Then you can verify Ohm's law yourself.

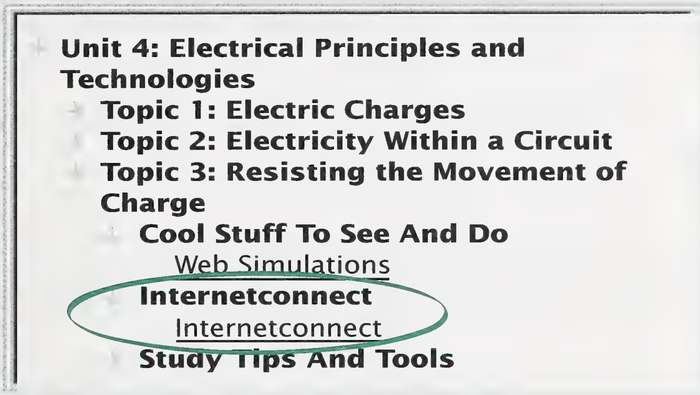
Compare your responses with those in the Appendix on page 82.

end of investigation

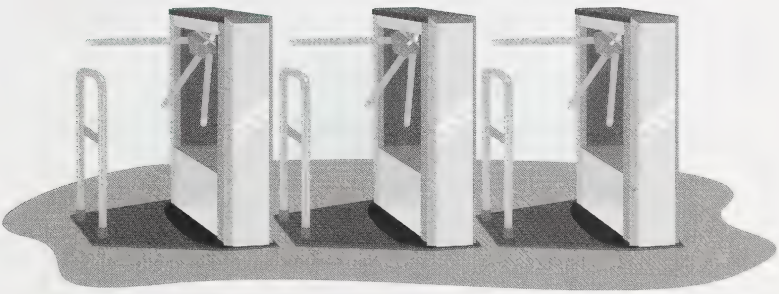
Did you ever wonder what those coloured bands on resistors are for? What's inside a resistor? Do the following "Going Further" to find out.

Going Further

Do the "Internet Connect" activity on page 285 of the textbook. Find out more about resistors. Go to **http://www.mcgrawhill.ca/links/sciencefocus9**. Then press "continue." Then navigate to the following link that's circled and click on it.



Types of Circuits



Can you imagine going to a concert for your favourite singer and discovering that only one turnstile works? Everyone must go through the same turnstile! And this is in an arena that seats several thousand people! You may get in for the last song—if you're lucky. Having many turnstiles open will get everyone to the show on time. In this case, having many paths has an advantage over a single pathway. Having many paths in an electric circuit also has advantages.

parallel circuit: *a circuit with more than one current path*

series circuit: *a circuit with only one current path*

The next textbook reading will help you distinguish between **parallel circuits** and **series circuits**.

Turn to page 286 of the textbook and read "Types of Circuits."

In the following investigation you will discover characteristics of each type of circuit.

Investigation 4C Series and Parallel Circuits

Refer to the "Inquiry Investigation" on pages 287 and 288 of your textbook.

Read the introductory information and then write your hypothesis. Copy the data tables in your notebook and record your predictions for each type of circuit.

Warning: Be sure that you use the correct bulbs. Two 1.5 V cells connected in a series can burn out a 2.5 V light bulb.

Part A: Series

Carry out the steps of "Procedure."

9. Answer question 1 of "Analyze," questions 2 and 3 from "Conclude and Apply," and questions 5 and 6 from "Extension." Note that these questions are on the left side of page 288.

Compare your responses with those in the Appendix on page 84.

Part B: Parallel

Carry out the steps of "Procedure."

10. Answer question 1 from "Analyze," questions 2 and 3 of "Conclude and Apply," and question 6 from "Extension." Note that these questions are on the right side of page 288.

Compare your responses with those in the Appendix on page 84.

end of investigation

Have you ever turned on a light switch and—surprise—nothing happens! Can you imagine the confusion if the one burned-out light bulb caused all the lights and electrical appliances in your house to fail?

Turn to pages 289 and 291 of the textbook and read "House Wiring." You'll find out why every light and appliance works independently of the others. As more lights and appliances are turned on, the current becomes greater. Power cable must be designed to handle this current flow without heating up.

11. Why does plugging in an electric kettle not dim the lights in the same room?

12. Do the "Pause and Reflect" feature on page 289 in your textbook.

Compare your responses with those in the Appendix on page 85.

Do the "Going Further" to design a circuit that allows you to turn light bulbs on or off and even dim them.

Going Further

Meet the challenge posed in "Problem-Solving Investigation 4D: Is Resistance Futile?" on page 290 of your textbook.

Obtain approval from your home instructor or teacher for any materials you plan to use. Do not construct your circuits until you've got the go-ahead from your home instructor or teacher.

This investigation is designed for a group—you may want to recruit several friends or family members to brainstorm with you.

There are switches in the household circuit that work as controls of the current. In microcircuits, circuits and components are miniaturized for use in computers, cell phones, and other advanced electronics. Microscopic diodes and transistors control the flow of current.

***diode:** a device that has two terminals and restricts the current flow between the terminals to one direction*

transistor: a device made of three layers so that a small voltage applied to the middle layer controls the current between the outer layers

A transistor controls the current going from one outer layer to the other outer layer.

Diodes, like one-way valves, allow current to flow in only one direction. **Transistors** act as switches. Transistors are constructed of three layers of treated silicon—they have no moving parts but can be switched between "on" and "off" simply by changing the voltage applied to the middle layer. Even microcircuits have the basic components of household circuits.

13. To test your understanding of the concepts in this lesson, answer questions 2 and 3 of "Topic 3 Review" on page 291 of your textbook.

Compare your responses with those in the Appendix on page 86.

Looking Back

In this lesson you studied the relationships between current, resistance, and voltage. You compared the effects on current when circuit elements are connected in series and in parallel. And you used the relationship known as *Ohm's law* to calculate resistance.

Lesson 4: Wrap-up

To review the concepts covered in this section, turn to page 292 in your textbook and answer questions 1 to 9 from "Wrap-up: Topics 1 to 3."

Check your answers with your teacher or home instructor.

Section 1 Conclusion

As you enjoy listening to music on your CD player, you don't have to think about the flow of electrons. But it's the electric nature of matter that makes your enjoyment possible.

The electric nature of matter and its atoms is basic to the role of electricity in your world. It's the mobile electrons of atoms that allow the electric current to flow. The function of technological devices depends on a flow of electricity.

In this section you studied the nature of electric charge. You distinguished between static and current electricity. You found that resistance to electron flow generates heat. Resistors, which have high resistance, can be used to control the amount of current and voltage in an electric circuit. You investigated electric current in series circuits and parallel circuits. Ohm's law was used to compare current, resistance, and voltage.

Turn to Assignment Booklet 4A. Complete questions 7 to 13 from Section 1.

Section 2

Energy Conversions

Imagine you have a basketball practice to go to. Your dad says he will drive you to the gym. When your dad turns the key to start the car, no lights come on and the engine barely turns.

"The battery is dead," your dad moans. He looks up to see a dim glow coming from the interior light. "Who left the inside light on?"

A car battery provides the electricity needed to turn the start motor—that is, if the battery is charged. There are many small electrical power sources that you rely on. Think of a calculator, a wristwatch, a cordless telephone, a flashlight, and so on. All use power sources that transform stored energy into electrical energy.

In this section you will focus on transformations between electricity and other forms of energy—thermal, mechanical, light, and chemical energy. You will investigate cells and batteries as technological devices that provide electrical energy through energy transformation.

Lesson 1: The Energy Connection

It's Ethan's turn to help out in the kitchen. He places a water-filled pot on the stove and turns on the element. It's not long before the water is hot. Ethan will use the hot water to prepare vegetable soup.

His mind is on food preparation—it's not on the energy transformation underneath the pot. That's where electricity is transformed into thermal energy.

Turn to page 293 of the textbook and read the top paragraph.

In the next activity you'll take stock of devices in your everyday life that convert one form of energy to another.

Find Out Activity Something to Electricity: Electricity to Something

Refer to the activity on page 293.

Read the opening paragraph, then carry out steps 1 and 2 of "Procedure."

1. Answer "What Did You Find Out?" questions 1 and 2.

Do you want to find out how devices work? Then you may want to do some research. A good place to start is the following site:

http://www.howstuffworks.com/

2. Here's an interesting chemical to electrical conversion. Read "Did You Know?" on page 299 of the textbook. The electroplaques, which are specialized muscle cells of eels, can generate about 0.15 V. How is it possible for an eel to generate a total voltage of about 600 V?

Compare your responses with those in the Appendix on page 86.

Electricity and Heat

Can you think of a device that converts thermal energy to electrical energy?

thermocouple: a loop of two wires made of different types of metals that converts heat to energy

Many home furnaces have a pilot light that has to stay on all the time. It lights the main burner. A safety device turns off the gas supply valve if the pilot light goes out. A **thermocouple** is the heart of the safety device. The thermocouple produces electricity only with the heat of the pilot light. An interruption in the flow of electricity signals the safety device to close the gas supply valve.

Turn to pages 294 and 295 of the textbook and read "Electricity and Heat" to find out more about thermocouples.

3. Does any combination of metals work for a thermocouple?

4. How is the thermopile in a thermo-electric generator built?

Compare your responses with those in the Appendix on page 87.

Electricity and Motion

You probably listen to music on a CD player. But some people still play vinyl records on a turntable. Many DJs like the turntable for its ability to add "scratch" sounds to music. The needle of the turntable normally follows along the squiggly grooves in a record spinning under it. A DJ may make the needle scratch across the grooves for a special effect. The vibrating movement of the needle is converted into electrical energy, which is amplified to run the speakers and produce the sound.

Maybe you can think of a device that directly converts electricity to motion or vice versa? No? The next reading will deal with such devices.

Turn to pages 295 and 296 of the textbook and read "Electricity to Motion" and "Motion to Electricity."

Read about the piezoelectric effect on pages 295 and 296 of the textbook, including the introductory paragraph of "Find Out Activity: Flashing Rocks."

5. Who first investigated the link between electricity and pressure?

6. Do other materials, aside from crystals, respond to an electric current with motion?

7. What is the job of the quartz crystal in a quartz clock?

Compare your responses with those in the Appendix on page 87.

Are you interested in seeing sparks? You can see them when you strike certain materials in a dark room. That's where the next "Going Further" takes you.

Going Further

To see the piezoelectric effect, complete one of the following.

- Light produced by applying pressure is a strange phenomenon. "Find Out Activity: Flashing Rocks" demonstrates the piezoelectric effect—light produced by pressure between two crystals. If you can find two large quartz crystals, put on your safety glasses and give it a try! Be warned that you will probably ruin the crystals!
- Obtain some Wintergreen LifeSavers. Chew them in the dark while looking at yourself in a mirror (or crush them with pliers). The "lightning" in your mouth is a result of the piezoelectric effect.

Electricity and Light

The International Space Station is completely powered by large panels of solar cells. These panels convert light energy to electrical energy.

You are probably familiar with more down-to-earth examples of light to electricity transformations. Just think about solar-powered calculators, watches, and roadside emergency phones.

Find out more about transformations of light and electricity in the reading on page 297 of the textbook.

8. What are the advantages of an LED over a conventional light bulb?

9. How does a solar cell produce electricity from light?

Compare your responses with those in the Appendix on page 87.

How much electricity can be produced by using solar cells?

Would solar cells be practical power sources for some battery-operated devices you use? If you would like to measure the current and voltage available from solar cells, do the next "Going Further."

Going Further

Refer to "Find Out Activity: Show Me the Light!" on page 298 of the textbook. If you can get some solar cells, use the steps of "Procedure" to guide your investigation.

10. To test your understanding of the concepts in this lesson, answer questions 2 to 4 of "Topic 4 Review" on page 299 of your textbook.

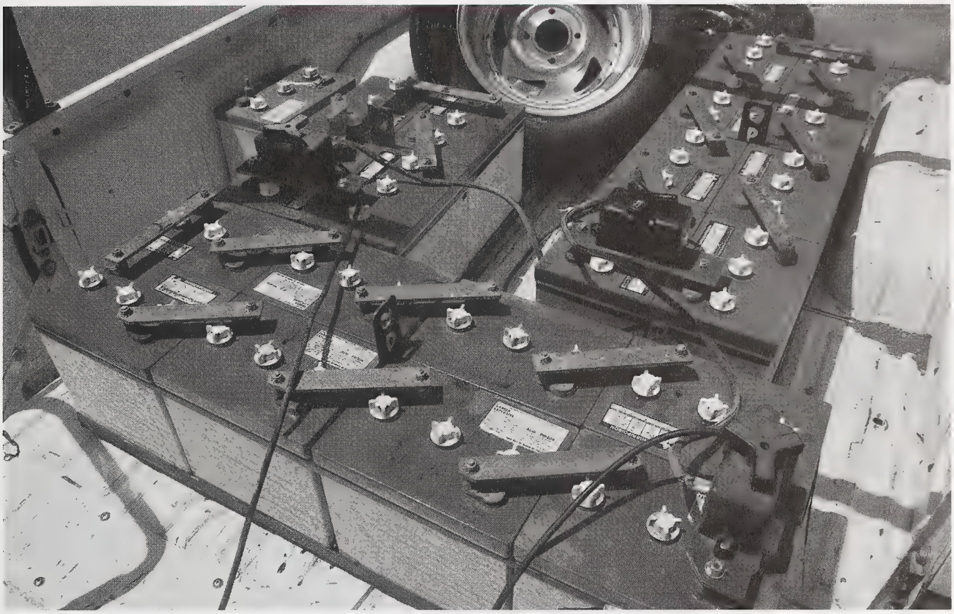
Compare your responses with those in the Appendix on page 87.

Looking Back

In this lesson you not only investigated the conversion of electric energy into thermal energy and other forms of energy. You also looked at the conversion of various forms of energy into electrical energy.

Turn to Assignment Booklet 4A. Complete questions 1 to 3 from Section 2.

Lesson 2: Portable Power



These batteries are in the back of an electric truck. When they're hooked up together, they can power the vehicle. The batteries provide a source of electric power on wheels.

In the early investigation of electricity, only a frog's tissue was known to produce an electrical current. Now it seems that batteries are everywhere. Laptop computers, mp3 players, personal CD players, digital cameras, camcorders, GPS receivers . . . all have batteries to power them on the go.

Go to your textbook for the history behind the development of practical sources of electricity.

Turn to page 300 of the textbook and read the topic introduction.

The voltaic pile was the first battery built. In the following activity you will construct an electrochemical cell using a method first demonstrated by Alessandro Volta in 1800.

Find Out Activity Pile of Power

Refer to the activity on page 300 of the textbook.

This activity requires that you use a millivolt scale because of the low potential difference produced. It may be necessary to switch to milliamps for a reading. Pay attention to positive and negative readings—you may have to switch the polarity. To switch polarity after you've pressed the leads into place, move the lead from the top of the cell to the bottom, and the lead from the bottom to the top.

To achieve results in this activity, use soft, thick, individual sheets of paper towel or two or three layers of a thinner variety. Clean the coins thoroughly with a steel wool pad before you use them. When testing, make sure you have good contact between the probes and the coins. Test a pile with a dry paper towel to see if electricity is produced.

Add heavy-duty aluminum foil to the textbook list in "Materials." Use the following steps if "Procedure" from the textbook fails to give you results.

When you add a second and third cell, make sure that a layer of paper soaked with saltwater separates each layer of metal.

Step 1: Cut some strips of aluminum foil about 2 cm × 4 cm and cut quarter-sized circles out of the paper towel. Soak the towel in the salt solution.

Step 2: Construct a single cell, similar to the one shown in the diagram at the bottom of page 300 of the textbook. Use the aluminum foil strip as the bottom layer and a penny as the top layer.

Step 3: Using the sides of the leads, press the leads from the voltmeter onto the top coin and the aluminum foil. (You don't want to poke holes in your aluminum foil.) Record the voltage produced.

Step 4: Repeat steps 2 and 3. Use a nickel, a dime, a quarter, and a loonie instead of the penny.

Step 5: Construct a two-cell battery using aluminum foil and pennies. And record the voltage produced.

Step 6: Repeat step 5 by using more cells, and then by using different coins.

1. Answer "What Did You Find Out?" questions 1 to 3.

Compare your responses with those in the Appendix on page 88.

Electrochemical Cells

Batteries I use don't even look like voltaic piles. I don't know what's inside them. Batteries are sure small compared to voltaic piles.

Modern batteries have allowed many devices to shrink in size. Huge advances have been made in miniaturization. For example, a cell phone from 1985 had a case the size of a large briefcase. The greatest gains in reducing the size of cell phones were made because batteries became smaller, more powerful, and longer lasting. Now a cell phone will fit in a shirt pocket.

Turn to page 301 of the textbook and read "Electrochemical Cells."

2. List the components of an electrochemical cell.

3. Study "Figure 4.30." Explain why the aluminum strip disintegrates in the electrochemical cell that is illustrated in "Figure 4.30."

4. Answer the question in the caption of "Figure 4.31." Give your reasoning.

Compare your responses with those in the Appendix on page 88.

How can you get "the most for your money" from a battery or electrochemical cell? Performance is the standard by which cells are measured. Wouldn't it be nice to know what factors affect performance?

Next, you will investigate factors that affect the performance of electrochemical cells. The next "Going Further" presents you with the option of doing your own research.

Going Further

If you have access to a teacher-supervised laboratory, physically carry out the "Procedure" steps in the next investigation. Note that distilled water can be purchased at drugstores. Don't substitute bottled water—it contains minerals. With "impurities" in the solution, water is an electrolyte.

You can use a saltwater solution instead of the sulfuric acid. But with saltwater as an electrolyte, you don't see bubbles forming on the electrodes. Your current and voltage will differ from those with a sulfuric acid electrolyte.

Investigation 4E Super Cell Sleuth

Refer to the “Inquiry Investigation” on pages 302 and 303 of the textbook.

5. Read through the introductory information. Then write your hypothesis.

A group of students working through the steps of “Procedure” obtained the following results.

Testing Wet Cells

Factor Changed	Electrodes	Electrolytes	Current (mA)	Voltage (V)	Action at Electrodes
Initial Reading	copper and zinc	sulfuric acid	250	1.1	bubbling at electrodes
After Running 5 Min	copper and zinc	sulfuric acid	220	1.1	bubbling continues, bubbles stick to electrodes
Wipe Bubbles Off	copper and zinc	sulfuric acid	250	1.1	bubbling resumes
Decrease Surface Area by Half	copper and zinc	sulfuric acid	130	1.1	decrease in bubbling
Use One New Electrode	aluminum and zinc	sulfuric acid	150	0.9	bubbles form on electrodes
Use Identical Electrodes	copper and copper	sulfuric acid	0	0	no bubbling
Change Solution to Water	copper and zinc	distilled water	0	0	no bubbling

6. Answer questions 1 to 6, 8, and 9 from “Analyze.” Base your analysis on the data table showing the students’ results. Note that question 7 is missing from the textbook.

Compare your responses with those in the Appendix on page 89.

Turn to Assignment Booklet 4A. Complete questions 4 and 5 from Section 2.

end of investigation

You have discovered certain factors that affect the performance of an electrochemical cell. Battery manufacturers take into account many more factors than you tested. The result is a wide variety of batteries on the market.

Turn to pages 304 and 305 of the textbook and read “Types of Cells.”

7. Match each purpose to its most appropriate cell. Write down the cell letters in the answer blanks to the left of each purpose.

____ **a.** cars	A. zinc air
____ **b.** cell phones	B. nickel-metal hydride
____ **c.** electric shavers	C. nickel cadmium
____ **d.** flashlights	D. lead acid
____ **e.** watches	E. alkaline

Compare your responses with those in the Appendix on page 90.

The performance of a battery is based on the performance of its individual cells. But the way the cells are connected to each other is also important.

Remember that the word *battery* is being used to refer to a group of two or more cells which are somehow connected together to provide an electric current. The cells don’t have to be packaged together—as in a car battery or a 9-V battery—to be considered a battery.

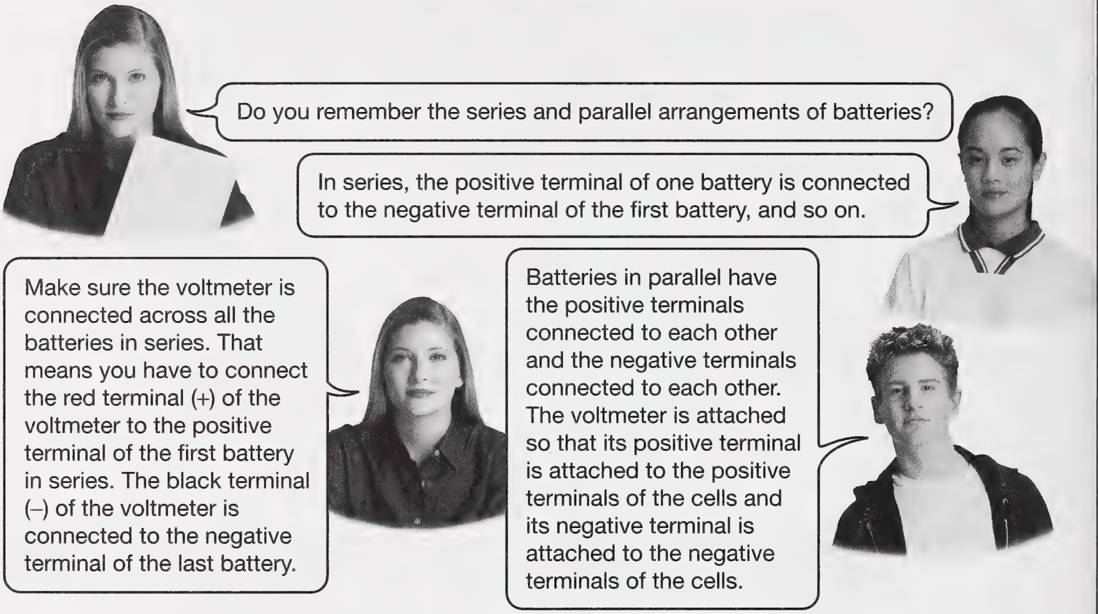
Do you need high voltage or long life in a battery? This question determines the design of a battery. In the following activity you will explore how connecting cells in series and/or in parallel affects a battery’s performance.

Investigation 4F Building a Battery

Refer to the "Problem-Solving Investigation" on page 306 of the textbook.

If possible, have your friends, family, or home instructor participate in the investigation with you.

You need three D-cells. Use two, 3.7 V bulbs as your load. Hook up the bulbs in series for two reasons. In series, the difference in brightness with changes in the battery design is more apparent. In series, the bulbs protect each other from burning out due to the high potential difference.



Carefully read the entire investigation. Carry out the steps of "Plan and Construct."

Don't leave the cells and bulbs connected longer than necessary to make your observations. Otherwise, bulbs and cells may be stressed.

8. Answer questions 1 to 5 from "Evaluate."

Compare your responses with those in the Appendix on page 90.

end of investigation

9. Turn to page 307 of the textbook and answer questions 1 and 3 of "Topic 5 Review."

Compare your responses with those in the Appendix on page 90.

Does using the "correct" cell or battery for the job make a little more sense now? Just fitting into the space provided or having the right voltage doesn't mean it's the best, or even the correct, choice of cell or battery.

Looking Back

In this lesson you investigated the fundamental principles of how electrochemical cells convert stored chemical energy into electrical energy.

Lesson 3: Wrap-up

To review the concepts covered in this section, do the following questions.

Turn to page 308 in your textbook and answer questions 1, 3, 5, 6, and 9 from "Wrap-up: Topics 4 to 5."

Check your answers with your teacher or home instructor.

Section 2 Conclusion

In the near future you may get around in an electric car. Its batteries will be charged by both solar power and electrical power. The car will depend on energy transformations that involve electrical energy.

Electrical energy is one of many forms of energy that include thermal energy, mechanical energy, light energy, and chemical energy. Energy can be transformed from one form to another that may be more useful.

In this section you studied the transformations between electricity and thermal energy, mechanical energy, light energy, and chemical energy. You investigated cells and batteries as applications of energy transformations between chemical energy and electrical energy.

Turn to Assignment Booklet 4A. Complete questions 6 to 10 from Section 2.

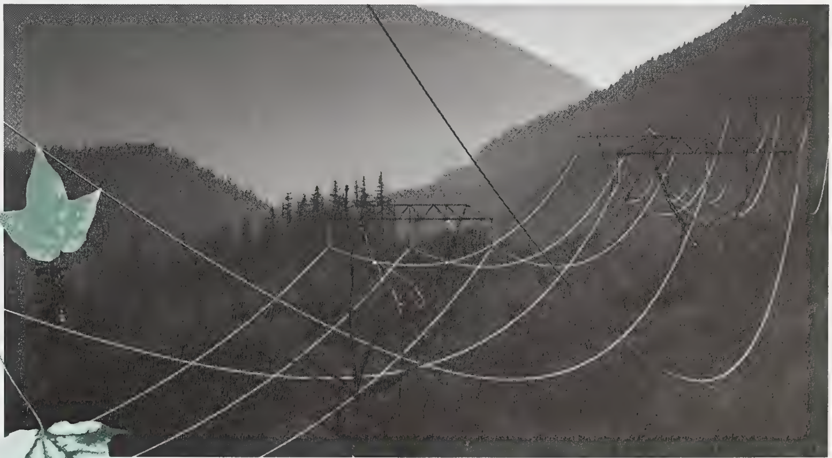
Section 3

Electricity Production, Distribution, and Use

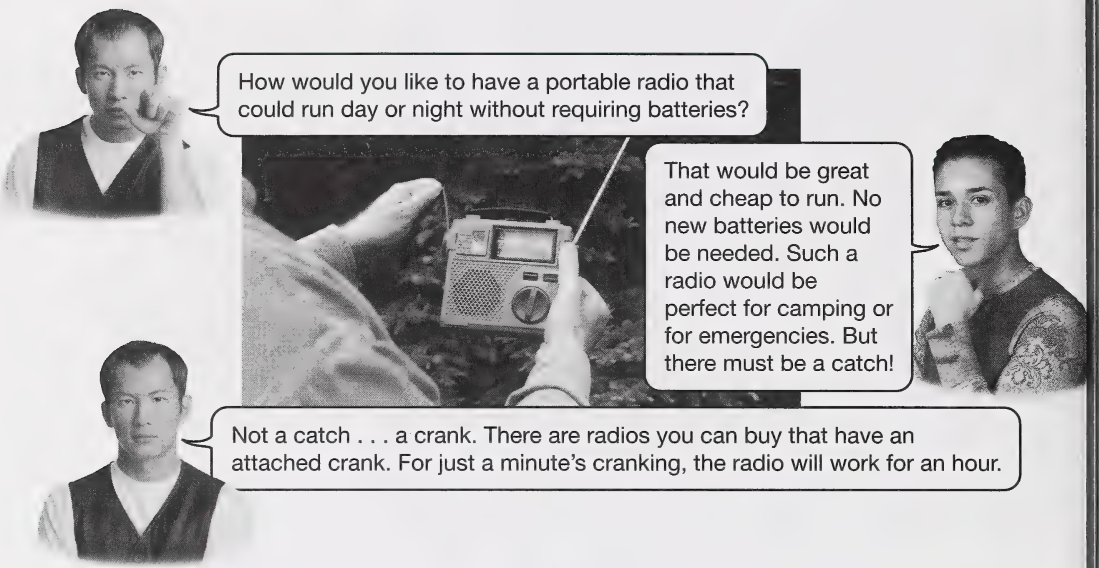
In your travels down the highway you may have spotted long power lines over the landscape. The lines were supported at great heights by colossal towers. Giant's steps could have paced off the distances between the towers. The lines seem to come from nowhere and go nowhere. Their solitude and silence contradict their importance.

These lines are vital. They carry immense amounts of energy to satisfy the needs of communities and industries that lie far beyond the horizon. And from where do the lines carry power? From power plants. To satisfy modern society's appetite for electrical energy, plants operate around the clock. These plants are often far away from the residential and industrial regions they serve.

Large-scale production is needed to serve both residential and industrial regions. This section is about the production of electricity and its use. You will explore the relationship between magnetism and electricity that allows generators to produce electricity. Also, you will explore the distribution of electricity to both residential and industrial users. You will consider alternative methods of electricity production and use. From these alternatives you will identify the methods that are most environmentally friendly.



Lesson 1: Generators and Motors



electric generator: *a device that converts mechanical energy into electrical energy*

electric motor: *a device that converts electrical energy into mechanical energy*

The crank turns an **electric generator**, which provides the electrical energy needed for the radio. In this lesson you will study the relationship between magnetism and electricity.

This relationship allows mechanical energy to be transformed into electrical energy. This relationship also allows electrical energy to be changed into mechanical energy—this is what happens in an **electric motor**.

Turn to page 309 of the textbook and read the topic introduction.

Hans Christian Oersted and André-Marie Ampère made an important observation in 1820. They reported an interaction between an electric current and a magnet. Eleven years later, Michael Faraday and Joseph Henry made a related discovery—they discovered that a magnet could produce a current in a conductor.

Now you can personally "discover" the effect of a magnet on a conductor. You'll have the advantage of using a very sensitive instrument to help you—a multimeter or a galvanometer.

Find Out Activity Electric Current-Generating Tube

Refer to the activity on page 309 of the textbook. Carry out the steps of "Procedure."

1. Answer "What Did You Find Out?" questions 1 to 3.

Compare your responses with those in the Appendix on page 91.

Magnetism and Electricity

Turn to page 310 of the textbook and read "Electricity to Magnetism" and "Electromagnets" for more information on the close relationship between electricity and magnetism.

2. Describe how an unmagnetized piece of soft iron differs from a magnetized piece of soft iron.

3. List three words Faraday is credited with introducing into the scientific vocabulary.

4. You generate electricity when you move a coil of wire relative to a magnet. What happens when you run an electric current through a coil of wire?

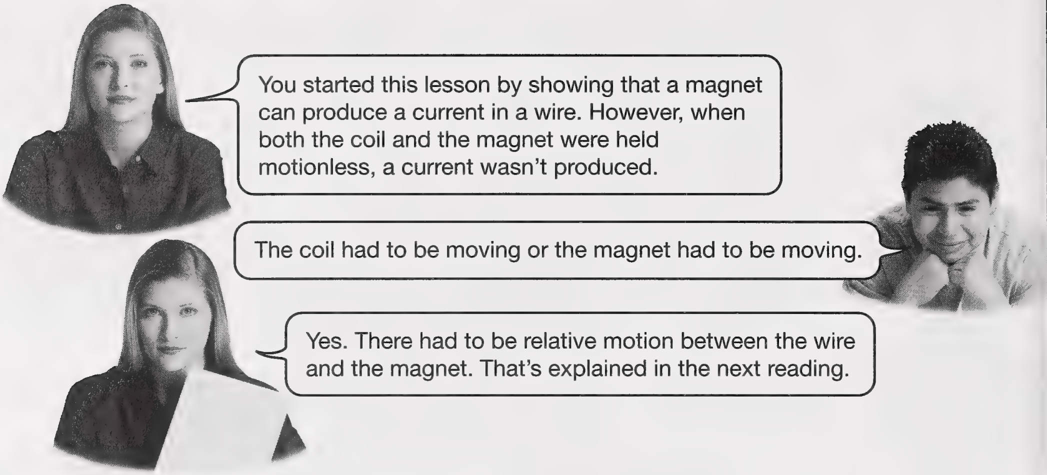
5. List three ways in which you can increase the strength of an electromagnet.

Compare your responses with those in the Appendix on page 91.

The reading mentioned certain factors that influence the strength of an electromagnet. You can apply this knowledge in the following "Going Further."

Going Further

Take the challenge! Gather your family and friends. See who can build the strongest electromagnet—the "most attractive" one. Follow the guidelines in "Problem-Solving Investigation 4G: The Attractive Electromagnet" on page 311 in your textbook.



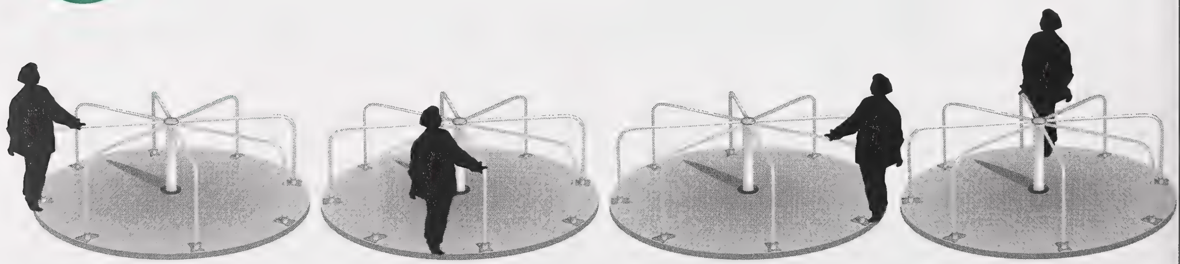
Turn to page 312 of the textbook and read "Magnetism to Electricity."

Refer to "Figure 4.35." The direction of the current depends on the direction in which the wire (or the magnet) is moved. With the wire moving back and forth, the current would flow one way and then the opposite way. With the wire moving back and forth regularly, the current would be **alternating**.

alternating: *reversing direction at regular intervals in a circuit*

In generating electricity in a practical way, a single wire is not moved back and forth. Instead, a coil of wire is rotated.

Read "What's in a Generator?" on page 313 of the textbook. Notice how the brushes have a sliding connection to the two wires coming from the rotating coil. In "Word Connect," find out why the automobile generators are called *alternators*.



alternating current: *a current that is produced by a generator and flows back and forth regularly*

Alternating current is abbreviated as AC.

When a coil of wire is rotated, individual segments of wire move back and forth inside the magnet. The back and forth action is like the movement of a person riding on the outside of a merry-go-round. From a distance you can see the person go from one side to the other, and so on. Due to the back and forth movement of individual wire segments of the coil, an **alternating current** is produced in the coil.

DID YOU KNOW?

In most countries of the world, alternating current is supplied at 50 Hz.

Turn to page 314 of the textbook and read "DC Generators."

Also read "Did You Know?" and carefully study "Figures 4.38A" and "4.38B."

6. Why would a split ring be used—rather than two separate rings—for the connection to the rotating coil?

Compare your response with the one in the Appendix on page 92.

A generator converts mechanical energy into electrical energy. Electricity can be converted back to mechanical energy by a motor. You use a motor for this energy conversion every time you use a garage door opener, a dishwasher, or a fan.

Turn to pages 315 and 317 of the textbook and read "Electric Motors: Electric to Mechanical Energy," "DC Motors," and "AC Motors."

7. A generator uses a coil inside a magnet to convert ____________ energy into ____________ energy. A motor uses a coil in a magnet to convert ____________ energy into ____________ energy.

8. Explain how the armature begins to rotate when the current from a battery is supplied in the DC motor shown in "Figure 4.39(a)."

9. Why does the armature not stop when the commutator shuts the current off in "Figure 4.39(b)?"

10. What is the role of the split-ring commutator in a simple DC motor?

11. What component functions as the field magnet in AC motors?

Compare your responses with those in the Appendix on page 92.

In the following investigation you will make a model of an electric motor by using simple materials. You will likely have to modify the design after test runs. The challenge is to make it spin continuously.

Investigation 4H Let's Get Motoring!

Refer to the "Problem-Solving Investigation" on page 316 in your textbook.

Read the entire investigation carefully; then follow the steps of "Plan and Construct."

Tips:

The key to success is to make sure the coil is symmetric—winding it around a broom handle or a wooden dowel will help. If the coil is asymmetric, it will not be balanced and will not rotate easily.

Pay special attention to how you make the split-ring commutator. The suggested split ring does not reverse the current in the coil each half rotation. It simply interrupts the current during the half of the cycle when the magnetic interactions would oppose the coil's rotation. That works because the coil momentum will maintain the rotation.

It's usually necessary to give the coil a gentle spin to get it started. Don't leave the coil sitting still, and not spinning, when the paper clips are connected to the cell. Parts can become hot and cause burns when you touch the coil.

Do you need ideas? Then play the *Science 9 Multimedia* CD and work through "Building a Motor."

12. Answer questions 1 and 2 of "Evaluate" and question 3 of "Extend Your Skills" from page 316 of the textbook.

Compare your responses with those in the Appendix on page 92.

end of investigation

In the early twentieth century, some science teachers in St. Louis, Missouri, designed a simple electric motor for instructional purposes. Today, St. Louis motors are still used for students. This type of motor has a real split ring and the parts are all exposed. The next "Going Further" focuses on this simple but revealing motor.

Going Further

Follow the "Internet Connect" on page 317 of the textbook to gain further insight into the workings of electric motors. Enter **http://www.mcgrawhill.ca/links/sciencefocus9** into your browser. Then press "continue." Then navigate to the following highlighted connection.

- **Unit 4: Electrical Principles and Technologies**
  - **Topic 1: Electric Charges**
  - **Topic 2: Electricity Within a Circuit**
  - **Topic 3: Resisting the Movement of Charge**
  - **Topic 4: The Energy Connection**
  - **Topic 5: Portable Power**
  - **Topic 6: Generators and Motors**
    - **Cool Stuff To See And Do**
    - **Internetconnect**
      - Internetconnect
    - **Study Tips and Tools**

13. To test your understanding of the concepts in this lesson, answer questions 1, 3, and 5 of "Topic 6 Review" on page 317 of your textbook.

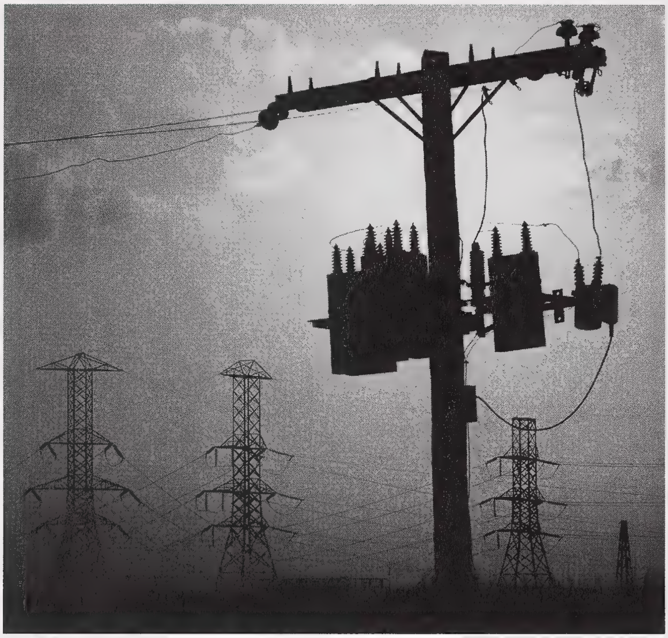
Compare your responses with those in the Appendix on page 93.

Looking Back

In this lesson you explored the relationship between electricity and magnetism. You investigated the design and function of electromagnets, generators, and electric motors.

Turn to Assignment Booklet 4B. Complete questions 1 to 4 from Section 3.

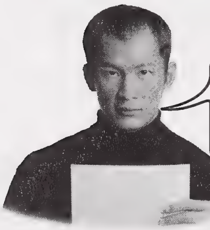
Lesson 2: Electricity in the Home



You walk into your room, turn on the desk light, start up your computer, and insert a disk into the CD-drive. The flick of a switch, the push of a button, and it's "magic" time.

You know how the electrical energy you use is produced. Have you thought about who pays the cost of producing it? And the production of electricity is only the start of its journey to your community and your home.

So, how does electricity get to our homes? Are the production costs split among the users? Or is the consumption measured and the cost determined by how much you use?



Your questions will be answered in this lesson, where you will investigate the distribution of electric energy. You will explore the cost of using electricity and the efficiency of electric devices.

From the Power Plant to Your Home

Albertans Without Power Sunday After Link Fails

Calgary Herald

CALGARY — Thousands of homes across Alberta were without power for up to 30 minutes Sunday after a key power supply from British Columbia failed.

A buildup of ice on major power lines linking Alberta to B.C. was the likely cause of what was one of the biggest power problems in the past 30 months, said Wayne St. Amour with the Power Pool of Alberta.

In Calgary, power went out at 3:33 p.m. in neighbourhoods across the city as giant circuit breakers shut down parts of the system.

Traffic was briefly snarled in parts of the city as signal lights were knocked out.

Calgary police Insp. Keith Pollock said there were no reports of accidents due to the traffic light problems.

The power started coming back on in Calgary at about 3:44 p.m.

Other parts of the province affected by the failure included Edmonton, Wainwright, Red Deer, Rocky Mountain House, Sundre, Coaldale, and Lethbridge, said Peter Symons of TransAlta, which supplies a number of rural and other city communities.

Since Alberta uses more power than it produces, the provincial power grid depends on British Columbia's excess production.[1]

Have you experienced a power outage? No light, no heat, no TV. You are more likely to have a power outage if there's a storm in your area. Electrical storms are often at fault. But there are times when there's a power failure due to a problem far away. A power failure may be due to a distribution problem in another province or even in the United States. That's because a power grid connects much of North America.

The power grid is the highway system for electrical energy. It delivers electricity from the generating station to your home and, with interprovincial and international connections, across North America. You are probably familiar with all the components of the grid. You have seen the high-voltage lines, substations, and transformers. Perhaps you're not familiar with their various functions. You may wonder what happens at substations or be curious about the transformer hanging on a power pole.

Turn to pages 318 to 320 of the textbook and read "Transmission of Electricity Through the Power Grid" and "From the Grid into Your Home."

To minimize line losses due to resistance, AC electric power is transmitted using high voltages (as much as 500 000 V) and relatively low currents. However, generators cannot produce the required high voltage.

---

[1] "Albertans Without Power Sunday After Link Fails," *The Calgary Herald*, 17 April 2000. Material reprinted with the express permission of "Calgary Herald Group Inc.," a CanWest Partnership.

1. How is the voltage increased at the power plant before transmission?

2. When does a circuit breaker "trip" to cut off the current? How is this achieved?

3. The terminals and wires in a battery circuit can be identified by the terms *positive* and *negative.* The polarity of AC changes continually, so *positive* and *negative* cannot be used to identify terminals or wires. Therefore, other terms in AC are used to identify the wires.

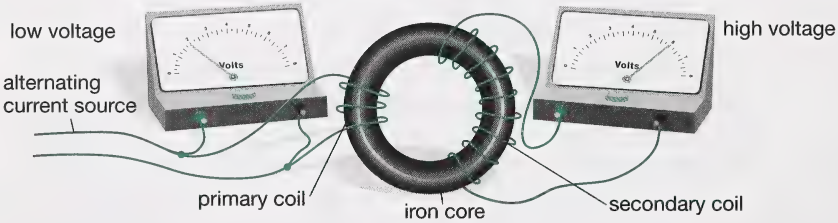
   a. A cable that carries household current has three wires in it. Name the three wires in such a cable and indicate how you can tell them apart.

   b. Normally, only two of the three wires carry the current. Which two wires carry the current?

Compare your responses with those in the Appendix on page 93.

Transformers can increase or decrease voltage. A transformer contains two coils of wire wrapped around a common iron core. The coil connected to the source of the AC is called the primary coil, while the other one is called the secondary coil. If the secondary coil has more turns than the primary coil, the voltage out of the transformer will be higher.

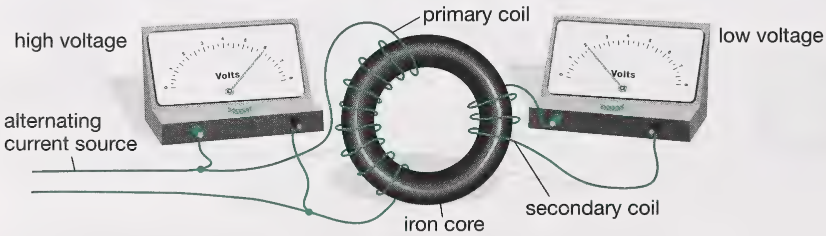
Step-up Transformer



A step-up transformer increases voltage.

If the secondary coil has fewer turns, the voltage out of the transformer will be lower.

Step-down Transformer



A step-down transformer reduces voltage.

The factor by which the voltage into and out of a transformer changes depends on the number of turns in the two coils.

Are you interested in building a type of transformer? Then you should go further.

Going Further

Turn to page 318 of the textbook and refer to "Find Out Activity: Build a Transformer." Use this activity to build a device that induces a voltage burst in a secondary coil.

Turn to pages 320 and 321 of the textbook and read "Home Wiring" and "Career Connect" to find out how electricians install wiring in your home.

4. Complete the following sentences. Use *parallel* or *series* to fill in the answer blanks.

   Each branch circuit is connected in ____________ with the metered power supply. The outlets are connected in ____________ within a branch circuit. The main circuit breaker is connected in ____________ with each branch circuit.

A Different Kind of Circuit

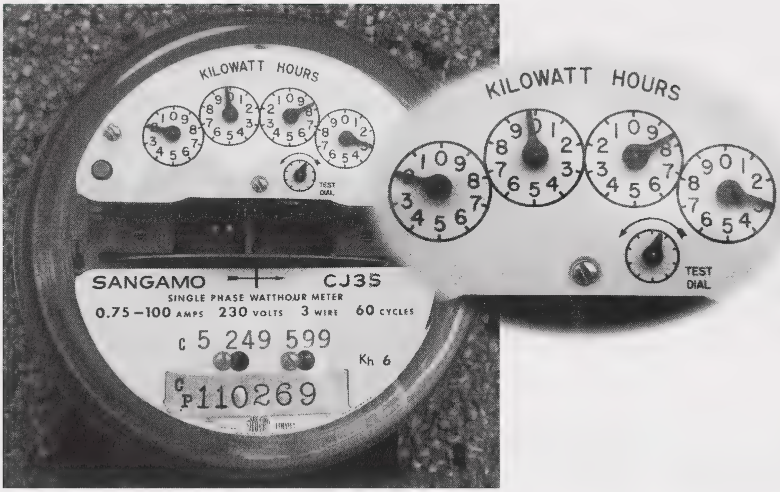
All electrical circuits have four basic components. These are a source, conductors, loads, and controls (switches). In a household circuit, and in the simple circuits you previously built, these components are easily identified. When you examine the circuit inside a calculator or computer, it becomes a little trickier to see—conductors are thin lines on a circuit board and switches are electronic rather than mechanical. Find out more about small-scale circuits in the next reading.

Turn to page 322 of the textbook and read "Digital Devices." Include "Did You Know?" and "Cool Tools" in your reading.

5. How does a microprocessor differ from an integrated circuit?

Compare your responses with those in the Appendix on page 94.

Measuring Electric Power



power: energy per unit time—especially the number of joules per second

1 J/s equals 1 watt.

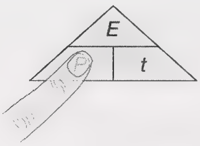
Turn to "Figure 4.45" on page 320 of the textbook. Note the meter "ahead" of the main circuit breaker. It acts as a sentry. No energy gets past the meter without being recorded. The rate at which energy is used is **power**. The greater the electrical power—the rate of electrical energy use—the faster the dials turn. The further the dials have turned since the last visit by the meter reader, the bigger the utility bill.

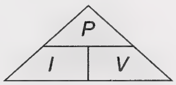
Turn to page 323 of the textbook and read "Measuring Electric Power." Also work through "Model Problem." Note the new units and symbols according to "Pause & Reflect."

Van and June discussed the reading and the model problem.

Van: There are just two basic formulas in the reading. The others are made by switching the variables around, aren't they?

June: Yes. I think we should put the basic formulas in a triangle. Then you can easily see the mathematical relationships among the variables. Just put your finger on the variable you want to evaluate. The two remaining variables will be in the right position.





For example, if you want to solve for power, P, from the first triangle, the position of energy, E, and time, t, indicates that energy is divided by time.

That is $P = \frac{E}{t}$.

By putting my finger onto E and then t, I get two more relationships.

$$E = P \times t \text{, and } t = \frac{E}{P}.$$

Van: That's easy to see. I'll apply the triangle idea to the other formula.

The second triangle represents the relationship among power, P, current, I, and voltage, V. By moving my finger over each variable in turn, I can see that

$$P = I \times V,\ V = \frac{P}{I}, \text{ and } I = \frac{P}{V}.$$

June: Be careful to put the variables in the right part of the triangle to begin with. Just think *P*ower is *V*ery *I*mportant—$P = V \times I$.

Van: Hey, *Very Important Person* works too. Let VIP stand for $P = I \times V$ backwards. I see some practice problems—we should be ready for them.

6. Do "Practice Problems" 1 and 3 from page 324 of the textbook.

Compare your responses with those in the Appendix on page 94.

Turn to pages 324 and 325 of the textbook and read "Paying for Electric Energy." Study "Model Problem."

7. Complete "Practice Problems" 1 and 2 on page 325.

Turn to page 326 of the textbook and read "Power Rating."

8. What do the large numbers on an EnerGuide label indicate?

Compare your responses with those in the Appendix on page 97.

In the following investigation you will analyze your personal use of electric energy, as well as your family's. You will investigate the cost of operating various appliances and devise a plan that could reduce your use of electrical energy.

Investigation 4I You've Got the Power!

Refer to the "Think and Link Investigation" on page 327 of the textbook.

Carry out the steps of "What to Do."

9. Answer the questions from "Analyze."

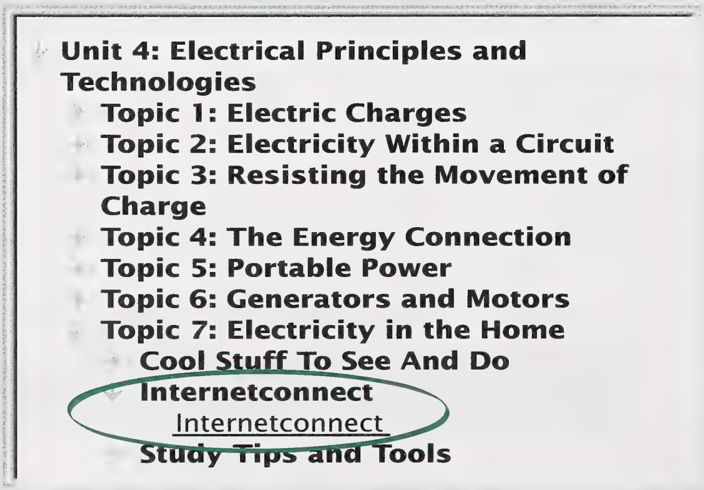
Compare your responses with those in the Appendix on page 99.

end of investigation

The next "Going Further" provides calculators to help see how you "spend" electrical energy at your home.

Going Further

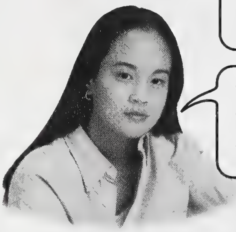
Learn to conserve. Save money and energy. Do the "Internet Connect" on page 326 of the textbook. Enter **http://www.mcgrawhill.ca/links/sciencefocus9** into your browser. Then press "continue." Then click the following circled "Internetconnect."



Efficiency

Suppose you were camping. After enjoying an evening campfire, it was time to douse the flames. You had to haul water to the fire pit from a water pump. However, the bucket had leaks. Every time you made the trip, you lost 1 L of water out of the 5 L you started with. You ended up having only 4 L of water to pour onto the fire. How efficient was hauling water with the leaky bucket?

I'd look at efficiency as the percentage of the pumped water that ended up in the fire pit. So the efficiency would be 4 L divided by 5 L times 100%. That equals 80%.



That's like the efficiency formula we learned in grade 8. The formula was based on the ratio of work done on the load and work done by the effort force.

The work done on the load is the output. The work done by the effort force is the input.

Yes. Expressed like that efficiency formula, water hauling efficiency equals output water divided by the input water, with all multiplied by 100%. And that equals 80%. The output water is the water that gets into the fire pit. The input water is the water you started out with from the pump.

When you use electrical devices you don't really lose energy. The law of conservation of energy says you don't. But only a portion of the input energy is converted into the intended form of output energy. The rest turns into a form of energy that is not useful—usually heat.

Turn to page 328 of the textbook and read the entire page.

10. Lighting devices differ in their efficiency.

a. An incandescent bulb is said to be about 5% efficient. What happens to the other 95% of the energy used?

b. Order the following light sources according to their efficiency, from least to most efficient. The list includes halogen bulbs, incandescent bulbs, and fluorescent tubes.

Turn to page 329 of the textbook and study “Model Problem.”

11. Do “Practice Problems” 1 to 3.

Compare your responses with those in the Appendix on page 100.

Electric Safety

To this point you have looked at beneficial applications of electricity. But there is a dark side. Heat is a by-product in all circuits and there is a danger of electric shock. Overloaded circuits or poor connections are a potential fire hazard. Touching exposed wires can be a shocking experience.

Turn to pages 330 and 331 of the textbook and read “Home Electric Safety” and “Electric Safety Outdoors.” Also read “Did You Know?” to find out about a device that may protect you from shocks when you get your feet wet.

Keep in mind that not all shocks are hazardous. “Cool Tools” deals with shocks that are life saving.

12. List some outdoor electrical dangers to be aware of.

13. What current level can cause a person to be unable to let go?

Compare your responses with those in the Appendix on page 104.

14. Turn to page 331 of the textbook. Answer questions 2 and 4 of “Topic 7 Review.”

Compare your responses with those in the Appendix on page 104.

Looking Back

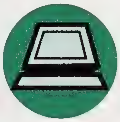
In this lesson you followed the path of electrical energy from the generating plant to your home. You discovered how users are charged for electricity. You calculated the efficiency of electrical devices. You examined your use of electric energy and what you could do to conserve this energy. Ways to use electricity safely in the home and in the yard were also identified.

Turn to Assignment Booklet 4B. Complete questions 5 to 7 from Section 3.

Lesson 3: Electricity Production and the Environment

Electricity is a clean energy—using electrical devices makes little impact on the air quality in your home or in the yard. But imagine following the power lines that serve your community. They'll take you to electricity generating plants. What impact do these plants have on the environment? That's what you'll investigate in this lesson.

In Alberta, and across Canada, electricity is generated in various ways. In the following activity you will look at data. Your analysis will reveal how the regions of Canada compare.



You will find that a computer spreadsheet will help you with the next activity.

Find Out Activity Seek the Source

Refer to the activity on page 333 of the textbook.

Note: With the exception of Prince Edward Island (P.E.I.) and the Yukon Territory (Y.T.), the numbers do not add up correctly on the map. British Columbia's (B.C.) total should be 66 698. Use the other provincial or territorial totals as they are given on the map. The totals present a reasonable picture. The map is not current—the territory of Nunavut is not shown. Keep in mind that you won't graph the data given for Prince Edward Island, the Yukon Territory, or the Northwest Territories because of their low totals.

1. Carry out the steps of "Procedure."

2. Answer questions 1 to 3 of "What Did You Find Out?" and questions 4 and 5 of "Extension."

Compare your responses with those in the Appendix on page 105.

Electric Energy from Burning Fuels

Thermo-electric generating plants provide most of the electricity in Alberta. Your textbook deals with thermo-electric generation on pages 332 and 336. Carefully read these pages and study the diagram on page 332.

3. What renewable fuel is being used in some thermo-electric generating plants?

4. What are three environmental concerns of using fossil fuels in thermo-electric power plants?

5. How can the amount of sulfur dioxide released into the atmosphere by thermo-electric generating plants be reduced?

6. Why is the release of carbon dioxide a concern?

Compare your responses with those in the Appendix on page 106.

What follows next is an investigation. You will analyze the efficiency of producing electric light from coal. You will also suggest improvements based on your analysis.

Investigation 4J Efficiency of Electric Lighting from Coal

Refer to the "Inquiry Investigation" on pages 334 and 335 of your textbook.

Read all the introductory information, and then carry out the steps of "Procedure."

7. Answer questions 1 and 2 of "Analyze" and question 3 of "Conclude and Apply."

Compare your responses with those in the Appendix on page 106.

end of investigation

Electric Energy from Flowing Rivers and Atomic Reactions

A large percentage of electric energy produced in Canada comes from hydro-electric plants. People have been using the energy from flowing water for a long time. On the other hand, thermo-nuclear generation is relatively new. Both types of energy are alternatives to thermo-electric generation. However, both alternatives have negative effects.

Turn to pages 337 and 338 of the textbook and read "Electric Energy from Flowing Rivers" and "Energy from Atomic Reactions."

8. List some of the negative environmental effects of a hydro-electric generating plant.

9. Why are nuclear power plants being phased out in Europe?

10. What type of nuclear reaction is potentially an environmentally friendly source of energy?

Compare your responses with those in the Appendix on page 107.

Heating the Environment

On a frosty winter's day you may have wished for a way to heat the environment. Electrical energy plants act like huge furnaces. They give off thermal energy—not enough to make their surroundings balmy, but enough to cause environmental problems. Such waste energy is called **thermal pollution**.

thermal pollution: the release of thermal energy due to warm water returning directly to the body of water from where it was taken

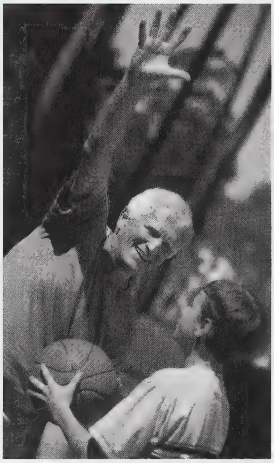
This increases the temperature of the body of water.

Turn to page 339 of the textbook and read "Heating the Environment." Then read "Cogeneration" to find out how waste thermal energy can be put to some use.

11. How do some plants reduce their thermal energy waste?

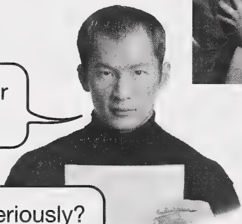
Compare your response with the one in the Appendix on page 107.

Alternative Energy Sources



Physical activities, such as playing basketball, require energy. The generation of this energy is due to human exertion and has little environmental impact.

The energy people need for homes and factories is far more than the energy used for human movement. There is a search going on for large-scale environmentally friendly alternative sources of energy to meet the needs of modern society. Turn to pages 340 and 341 of the textbook and read "Alternative Energy Sources."



The alternative energy sources described in your textbook have been available for some time.

So, why is it just now that they're being taken seriously?

There are several reasons. The cost of some energy alternatives is falling. For example, solar farms can now be built more cheaply than before. Also, resources are being used up—there is now a greater awareness of the environmental costs.

12. What is the minimum average windspeed required to establish a large-scale wind farm in a particular location?

13. Why are solar cells not very practical for large-scale power generation?

14. What is one potential pollution problem that results from geothermal generation? How can this be prevented?

Compare your responses with those in the Appendix on page 107.

Going Further

Research an alternative of your choice. Follow "Find Out Activity: Alternative Methods of Generating Electricity" on page 342 of your textbook.

15. Turn to page 342 of the textbook and answer questions 1 and 4 of "Topic 8 Review."

Compare your responses with those in the Appendix on page 108.

Looking Back

In this lesson you studied the production of electricity in Canada and its impacts on the environment. You thought of ways to minimize negative impacts on the environment. You considered alternative ways to generate electricity, and you looked at how suitable these alternatives would be for Alberta.

Lesson 4: Wrap-up

To review the concepts covered in this section, turn to page 343 in your textbook. Answer questions 1, 2, 8, and 9 of "Wrap-up: Topics 6 to 8."

Note: For question 1, include the term *watt* in the list of terms to choose from.

Check your answers with your teacher or home instructor.

The final project for this module may bring out the inventor in you!

Going Further

Read "My Amazing Electrical Invention" on pages 346 and 347 of the textbook. Then start planning.

Build and then test your device only after your teacher or home instructor has approved your plans.

Section 3 Conclusion

In this section you studied the electromagnetic principles. These are the facts that make electromagnets, electric motors, and generators possible. You calculated power and the cost of electric energy. You expressed energy efficiency as a percentage. You looked at the generation of electric energy. You saw how electric power is distributed to users. You assessed environmental impacts and explored alternative sources of energy.

The use of electricity involves production and distribution—these do have environmental impacts. However, it's hard to think about living without electricity.

Without huge power lines and transmission towers, the lifeblood of modern living would never reach your community and home. And that would leave you without a lamp, a microwave, a TV, and the list is endless. Yet, decisions must be made about the production and consumption of electricity. In these decisions, societal and environmental concerns need to be recognized.

Turn to Assignment Booklet 4B. Complete questions 8 to 10 from Section 3.

Module Summary

Have you ever experienced a lightning storm? You may have heard an explosive sound of thunder. This sound was due to an immense release of power. You have seen tree trunks split by a lightning strike. Lightning is a form of electricity that is unbridled and out of control. Electricity out of control is dangerous rather than desirable. Lightning is a leading cause of human fatalities among weather-related events. However, electricity as a controlled current is at the heart of modern living.

In this module you described electric current, and you explored the relationships between current, voltage, and resistance in electric circuits. You investigated energy transformations involving electric energy and the large-scale generation and transmission of electricity to homes and industries. You also studied various sources of energy and their environmental impacts.

Module Review

To review the concepts covered in this module, turn to page 348 in your textbook and study the concepts listed in "Unit at a Glance." To help test your understanding of the concepts covered in this module, answer questions 10, 13, 16, 28, 32, 36, and 38 from pages 349 to 351.

Attention: Question 13 should read 57 kJ rather than 5.7 kJ. In question 32, the line for *E* should point at the rectangular block attached to the vertical shaft.

Check your answers with your teacher or home instructor.

Turn to Assignment Booklet 4B. Complete the Final Module Assignment.

Appendix

Glossary

Suggested Answers

Image Credits

Glossary

alternating current: a current that is produced by a generator and flows back and forth regularly

Alternating current is abbreviated as AC.

ammeter: an instrument used to measure the rate of flow of electricity

ampere (A): the SI unit for electric current

armature: a coil of wire formed around an iron or steel core mounted on a shaft

It rotates in the magnetic field of a generator or a motor.

battery: a combination of wet or dry cells

binary code: code that is based on two states (on or off) and that represents numbers and letters

branch circuit: each current path in a parallel circuit

circuit breaker: a switch that can turn itself off when current flow exceeds a safe limit

cogeneration system: an electricity generation station that also supplies thermal energy for useful purposes

commutator: the split ring of a motor or generator which, in combination with brushes, provides an electrical connection to the rotating coil of the armature

conductor: a material along which an electric charge can readily move most metals

diode: a device that has two terminals and restricts the current flow between the terminals to one direction

A diode can be used to convert AC to DC.

direct current: a current that flows in only one direction

Direct current is abbreviated as DC. Batteries produce DC.

dynamo: a type of electricity generator that produces direct current

efficiency: the ratio of useful output energy from a system to the input energy supplied to the system

Efficiency is usually expressed as a percentage.

electric circuit: the complete path of an electric current

electric current: a flow of electric charge; the rate of such flow measured in amperes (A)

electric generator: a device that converts mechanical energy into electrical energy

electric motor: a device that converts electrical energy into mechanical energy

electrochemical cell: a combination of two electrodes arranged so that an overall oxidation-reduction reaction produces an electric potential difference

Examples are dry cells, wet cells, or fuel cells.

electrolyte: a non-metallic electric conductor in which current is carried by the movement of ions and in which electrodes are placed

electromagnet: a temporary magnet made by inserting an iron core into a coil of wire and then passing a current through the wire

force: a push or pull (N)

fuse: a safety device containing a metallic conductor that melts when heated by excessive current

geothermal energy: thermal energy contained in the inner portion of Earth

greenhouse gases: gases that hold in heat from the Sun in the atmosphere

Greenhouse gases help control the temperature of the atmosphere.

ground wire: a wire that safely carries electrical energy that "leaks" out

The ground wire in electrical cable is either bare copper or covered with green insulation.

heat: thermal energy that transfers from a warmer substance to a cooler one

hot wire: one of the "live" wires in electric cable that, along with the neutral wire, carries the electrical energy

The hot wire is covered with black insulation.

hydro-electric plant: a plant that uses water pressure to generate electric energy

insulator: a material along which an electric charge does not readily move

Most non-metals are insulators.

joule (J): a unit of energy; a newton-metre ($N \bullet m$); the amount of work done when a 1 N force moves an object 1 m

kilowatt hour ($kW \bullet h$): a unit used to measure the amount of electrical energy used by a device or system

1 $kW \bullet h$ equals the amount of energy used when 1000 W of power is used for 1 h. For example, that's the amount of energy used when ten 100 W bulbs are kept on for 1 h.

law of conservation of energy: the law that states that energy can be neither created nor destroyed, but it can be converted from one form to another

Input energy equals output energy.

laws of charges: the laws that state the following about the behaviour of charged and uncharged objects:

- Unlike charges attract.
- Like charges repel.
- Charged objects attract uncharged objects.

load: a device in electric circuits that transforms electrical energy into another form of energy; e.g., resistor, motor

microcircuit (integrated circuit): a solid-state electronic circuit created on an extremely small scale (as many as one million components per square cm)

neutral wire: one of the "live" wires in electric cable that, along with the hot wire, carries the electrical energy

The neutral wire is covered with white insulation.

newton (N): the SI unit of force (weight); 100 g of mass weighs 1 N

non-renewable resources: fuels that are consumed faster than they are replaced by nature

nuclear fission: the energy-releasing process whereby uranium nuclei are split into smaller nuclei

ohm (W): the SI unit for electric resistance

Ohm's law: the law stating that the resistance of a component equals the potential difference across the component divided by the amount of current through the component

ohmmeter: an instrument to measure electric resistance

open-pit mining: mining in which fuel is uncovered and dug directly from the ground

parallel circuit: a circuit with more than one current path

photovoltaic cell: a device that converts light into electric energy

potential difference: the difference in electrical potential energy per unit of charge between two points in an electric circuit

This is also referred to as voltage.

power: energy per unit time—especially the number of joules per second

1 J/s equals 1 watt.

primary cell: a cell that delivers an electric current as a result of an electrochemical reaction that is not easily reversible; a cell that cannot be recharged

qualitative data: information that is not numerical in nature

quantitative data: data that consist(s) of numbers and units of measurement

renewable resource: any natural resource that can be replenished naturally over a period of time

resistance: the property of a substance that hinders the flow of electric current and that converts electric energy into other forms of energy, for example, heat and light

resistor: an electric device that has electrical resistance

A resistor is often used in an electrical circuit for current and voltage control.

rotor: the rotating core of an alternating current motor

scrubbers: antipollution systems that remove sulfur dioxide and contaminating gases which result from the burning of fossil fuels

secondary cell: an electrolytic cell which, after being discharged, may be recharged by sending a current through it in the direction opposite to the discharging current

semiconductor: a solid crystalline material that has an electrical conductivity between that of a conductor and an insulator

series circuit: a circuit with only one current path

static electricity: stationary electric charges

stator: the stationary part of a motor that contains the magnetic circuit and its windings

superconductor: a material that offers little or no resistance to electric charge flow

switch: a control device for making or breaking connections in a circuit

thermal pollution: the release of thermal energy due to warm water returning directly to the body of water from where it was taken

This increases the temperature of the body of water.

thermocouple: a loop of two wires made of different types of metals that converts heat to electrical energy

A temperature difference between the metals produces a potential difference. A thermocouple can be used to convert thermal energy into electric energy or to measure temperature.

thermo-electric generator: plants that burn fossil fuels to produce electricity

thermonuclear electric generation: the generation of electrical energy using the energy released in nuclear fission

transformer: a device consisting of two or more wire coils in close proximity to one another

A transformer is used to transfer electric energy from one alternating current circuit to another, and to step-up or step-down voltage.

transistor: a device made of three layers so that a small voltage applied to the middle layer controls the current between the outer layers

A transistor controls the current going from one outer layer to the other outer layer. A transistor is called a solid-state device because it has no moving parts.

volt (V): the standard SI unit for electric potential

voltage: the difference in potential energy per unit charge between two points in a circuit; also called electric potential difference

voltaic cell: a cell that delivers electric current as a result of an electrochemical reaction that is not easily reversible; a cell that cannot be recharged

A voltaic cell is also called a primary cell.

voltmeter: an instrument used to measure electric potential difference

watt (W): the SI unit for power; 1 J/s

work: the transfer of energy from one object or system to another when a force is applied over a distance

Suggested Answers

Section 1: Lesson 1

1. **Textbook questions 1 to 3 from "What Did You Find Out?" on page 267:**

   1. **(a)** Uncharged (neutral) strips do not react to one another.

      (b) Charged strips of the same material repel one another. Charged strips of different materials attract one another.

   2. No, charged strips did not always behave the same. Charged strips of the same material, and therefore the same charge, repel one another. Charged strips of different materials, and therefore different charges, attract one another.

   3. Three rules are as follows:

      - Charged objects attract uncharged objects.
      - Objects with similar charges repel one another.
      - Objects with different charges attract one another.

2. A neutral material that has lost electrons has more protons than electrons. It will have a positive charge. A neutral material that has gained electrons has more electrons than protons. It will have a negative charge.

3. Franklin chose to call the charge on amber *negative* and the charge left on fur *positive*.

4. **a.** Glass is an insulator—placing the strips of material on the watch glass isolated the strips electrically. Electrons could not leave or enter through the glass.

   b. Both acetate and vinyl are insulators. Electrostatic charges could be accumulated on one end of the strips while the other end was in contact with your hand. If they were conductors, a charge would not build up. The electrons would disperse through the materials—this would keep the electrons neutral.

5. The chemicals dissolved in the water affect its ability to conduct electricity. Salty water is a fair conductor because of the salt ions in the solution. Distilled water consists almost entirely of electrically neutral water molecules.

   Note: You may want to review the information on ions—an atom or group of atoms with a net positive or negative charge—and conductivity on page 140 of the textbook. In a liquid or gas (fluid), both positive and negative ions are free to move—either can carry the charge or carry an electric current.

6. **Textbook question from "Pause and Reflect," page 269:**

Answers will vary. Note the following table for some examples.

Conductivity Applications		
Good Conductors	**Fair Conductors**	**Insulators**
most wires (house wiring, telephone lines, speaker wires) and electric cords	stove elements	switch plates
	hair dryer elements	outlet plates
cell and battery terminals	toaster elements	telephone hand pieces
contacts on computer chips	volume controls	handles for electrical devices
	dimmer switches	

7. Superconductors only function at very low temperatures. This makes any superconducting application very costly and impractical for household use.

8. Connecting an object with a conductor to Earth is referred to as *grounding*. The procedure provides a conducting path for electric charges from the object to Earth (or a surface connected to it). An object that is initially charged will lose its charge when grounded.

   Note: Your body can act as a "path to ground." Death or injury could be the result if the discharge or current is large enough (e.g., a lightning strike or accidentally touching a live, uninsulated wire). Earth acts like a reservoir for electric charges and readily accepts or provides electrons to a charged object.

9. An electrostatic charge buildup causes objects to stick to one another. This causes static cling, jammed photocopiers, and a buildup of dust on charged objects—such as your television screen.

10. **Textbook question 1 of "Topic 1 Review," page 271:**

    1. Answers will vary. Note the following, which outlines two examples of each law:

       - opposite charges attract—electrostatic air cleaners or dust being attracted to a plastic broom
       - like charges repel—hair standing on end after pulling a sweater over your head or sugar grains flying off a plastic spoon
       - charged objects attract uncharged objects—"static cling" of cloth to your skin or plastic wrap clinging to a dish

Section 1: Lesson 2

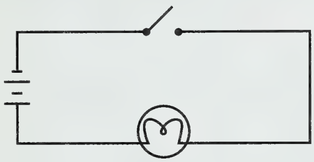
1. Check your answers with your teacher or home instructor.

2. a. D
   b. A
   c. C
   d. C
   e. D
   f. B

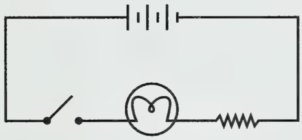
3. A battery consists of a group of cells that are connected together.

4. Answers will vary. The following are sample answers only.

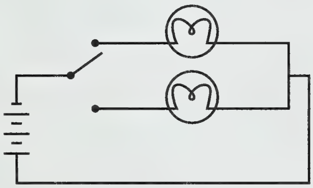
   a.



   b.



   c.

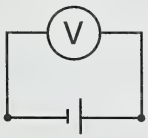


5. Electrons must move through a conductor to create an electric current.

6. Both a *galvanometer* and an *ammeter* are meters used to measure electrical current. The *ammeter* is used to measure strong currents, whereas the *galvanometer* is used to measure currents too small for the *ammeter*.

7. a. The standard unit for potential difference is the volt (V).
   b. This unit is named after Alessandro Volta, who built the first battery (voltaic pile).

8. Your diagram should be similar to the following.



9. **a.** B
   b. A
   c. A
   d. B
   e. C

10. **Textbook questions from "Instant Practice," page 490.**

    a. The value at "Figure 6A" is 6.5 V DC.
    Note: Use the middle series of numbers.

    b. The value at "Figure 6B" is 285 V DC.
    Note: Use the lowest series of numbers.

    c. The value at "Figure 6C" is 8.8 V DC.
    Note: Use the top series of numbers.

    d. The value at "Figure 6D" is 44 mA DC.
    Note: Use the top series of numbers.

11. A sample answer follows.

    I am using a single 3.7 V load in this circuit instead of a 2.5 V load because two cells combined may produce a potential difference (voltage) that exceeds the nominal voltage of the 2.5 V bulb.

12. **Textbook questions 1 to 3 of "Analyze" and questions 4 and 5 from "Conclude and Apply," page 276:**

    1. The current is the same at points A and D. That's because the current is the same throughout a circuit.

    2. The current will be the same because the current going into the light bulb is the same as the current going out of the light bulb. Electrons do not accumulate inside the bulb.

    3. Opening the switch stopped the current from flowing. Closing the switch started the current flowing.

    4. For the current to flow the battery must be connected, the switch must be closed, and the bulb must be in good condition. Also, the conducting wire must be sound and the connections must be good. If the bulb is burned out, the pathway for the current will be broken.

5. The following factors affect the current:

    - the number of cells because this affects the voltage
    - the nominal voltage of the bulbs because this may be related to the actual resistance of the bulbs
    - the length of the conducting wire because path resistance is affected by path length

13. Textbook questions 1 to 4 of “Analyze” and question 5 from “Conclude and Apply,” page 277:

1. **(a)** The D cells provide the electrical energy.
   (b) The bulbs use electrical energy.

2. The potential difference across the whole load was almost equal to the voltage at the battery terminals.

3. The energy provided by the battery is equal to the energy used by the light bulbs. This is indicated by the voltage readings.

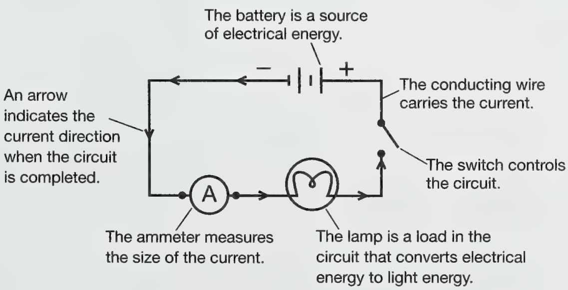
4. The voltages across each individual bulb add up to the voltage across the whole load.

5. With the 3.7 V bulb in place, the 2.5 V bulb did not glow at all when the circuit was closed. The voltage across the 3.7 V bulb was much larger than across the 2.5 V bulb. Therefore, most of the electric energy conversion took place in the 3.7 V bulb. That’s why the 3.7 V bulb emitted more light and heat.

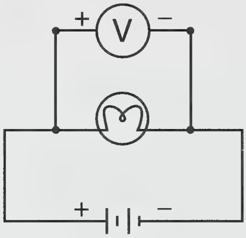
14. **a.** The highest energy is at point 1.
b. The control is at point 3.
c. The load is at point 4.

15. Textbook questions 2 and 3 of “Topic 2 Review,” page 278:

2. Your circuit diagram should look similar to the following one.



3. The voltmeter is connected across the load. The positive post of the meter must be on the side of the load closest to the positive terminal of the battery, and the negative post must be closest to the side of the negative terminal.



Section 1: Lesson 3

1. A light bulb filament converts electrical energy into thermal energy and light energy.

2. A good conductor has *low* resistance. Poor conductors have *high* resistance. An *ohm* is the standard unit for resistance. Resistance is measured with an *ohmmeter*.

3. **Textbook questions 1 to 3 of "What Did You Find Out?" on page 280:**

   1. The current decreased as the length of wire, and therefore the resistance, increased. Fewer electrons were able to pass.

   2. As resistance increases, the current decreases.

   3. The lower the current, the dimmer the light bulb. If fewer electrons pass through the bulb, it will receive less electrical energy. The resistance in the Nichrome wire would also decrease the voltage left for the bulb by converting electrical energy into thermal energy.

   Textbook questions 1 and 2 of "Extension," page 280:

   1. The Nichrome wire converted electrical energy into thermal energy. The wire felt hot.

   2. Heating elements in stoves, ovens, hair dryers, toasters, and light bulb filaments have resistance to produce heat. They get hot.

      Resistance is also used to change the volume of televisions and radios, the speed of a blender motor, and the brightness of a light bulb in its fixture.

4. *Ohm's law* is an empirical relationship among resistance, current, and voltage. It states that resistance is equal to voltage divided by current.

   $R = \frac{V}{I} \qquad V = IR$

5. Textbook questions 1 to 3 from "Practice Problems," page 282:

1. Given

$I = 2.4$ A
$V = 12$ V

Required

Resistance, R, in ohms (Ω)

Analysis

Use the expression $R = \frac{V}{I}$ to find resistance.

Solution

$$R = \frac{12V}{2.4A} = 5.0\,\Omega.$$

Paraphrase

The resistance of the bulb is 5.0 Ω.

2. Given

$R = 145$ Ω
$V = 120$ V

Required

Current, I, in amps (A)

Analysis

Use the expression $I = \frac{V}{R}$ to find current.

Solution

$$I = \frac{120\ V}{145\ \Omega} = 0.828\ \text{A}$$

Paraphrase

A current of 0.828 A will flow through the toaster.

3. **Given**

$R = 1500\ \Omega$
$I = 0.075\ \text{A}$

Required

Voltage, V, in volts (V)

Analysis

Use the expression $V = IR$ to find voltage.

Solution

$$\begin{aligned} V &= IR \\ &= 0.075\ \text{A} \times 1500\ \Omega \\ &= 112.5\ \text{V} \end{aligned}$$

Paraphrase

The potential difference across the resistor is 112.5 V.

6. Thermistors are used in thermostats and heat sinks.

   Rheostats are used in high-current electric circuits, such as electric power distribution equipment.

7. The wording will vary but the hypothesis should be a statement reflecting Ohm's law $\left(R = \frac{V}{I}\right)$.

8. **Textbook questions 1 and 2 of "Analyze" and 3, 4, and 6 of "Conclude and Apply," page 285:**

   1. The electric current increased as the voltage increased.

   2. For similar voltages, the current passing through a resistor with higher resistance is lower.

3. You may have used a spreadsheet with formulas as shown.

	A	B	C	D	
1					
2					
3	Electric Current, Voltage, and Resistance				
4	Resistor	Voltage (V)	Measured Current (mA)	Calculated Resistance (Ω)	
5	Resistor No 1	1	32	=B5/(C5/1000)	
6	R = 30 Ω	2	68	=B6/(C6/1000)	
7		3	100	=B7/(C7/1000)	
8		4	130	=B8/(C8/1000)	
9		6	200	=B9/(C9/1000)	
10	Resistor No 2	1	16	=B10/(C10/1000)	
11	R = 60 Ω	2	34	=B11/(C11/1000)	
12		3	50	=B12/(C12/1000)	
13		4	67	=B13/(C13/1000)	
14		6	101	=B14/(C14/1000)	
15					
16					

Your calculated resistance column should have the following values.

Electric Current, Voltage, and Resistance			
Resistor	**Voltage (V)**	**Measured Current (mA)**	**Calculated Resistance (Ω)**
Resistor 1 **R = 30 Ω**	1.0	32	31
	2.0	68	29
	3.0	100	30
	4.0	130	31
	6.0	200	30
Resistor 2 **R = 60 Ω**	1.0	16	63
	2.0	34	59
	3.0	50	60
	4.0	67	60
	6.0	101	59

4. The calculated values of resistance should be close in each case. Discrepancies are due to the

   - power supply voltages
   - varying resistance due to the looseness of connections
   - heating of the resistor
   - accuracy in the readings of voltage and current

6. The results should reflect Ohm's law. The calculated values based on Ohm's law were close to the measured values.

9. Textbook question 1 from "Analyze," questions 2 and 3 from "Conclude and Apply," and questions 5 and 6 from "Extension," all from "Part A," page 288:

1. The brightness of the bulbs decreases as more bulbs are added. The current also decreases.

2. The brightness decreases because less current flows due to an increase in resistance. Each new load adds more resistance to the circuit.

3. Unscrewing one light bulb caused all of the bulbs to go out. There is only one path for the electrons in a series circuit. Removing a bulb creates a gap in (it opens) the circuit so that the electrons can no longer flow.

5. A simple flashlight is a series circuit with one load. Old models of holiday lights or new inexpensive holiday lights are wired in series.

6. Advantages include the following:

   - simple to build
   - uses less wire
   - "serial dimming effect" useful for some applications
   - works well with one or two loads

   Disadvantages include the following:

   - One burnt-out bulb shuts down the whole circuit.
   - Bulbs become dimmer and may not even light as more are added.

10. Textbook question 1 from "Analyze," questions 2 and 3 of "Conclude and Apply," and question 6 of "Extension," all from "Part B," page 288:

1. The brightness of the bulbs stays more or less the same as more bulbs are added. The ammeter reading increased as bulbs were added.

   Note: If the cells used are weak, some dimming may be noticed.

2. The current released by the battery increased as more bulbs were added in new pathways. The resistance within each pathway would be about the same for bulbs of the same voltage. More electrons can flow at one time with multiple pathways (until the battery's maximum output has been reached).

3. Unscrewing one bulb did not affect the others. Each bulb has its own complete current path. A current can flow through any closed pathway.

6. An advantage is that all equal loads receive a current. Also, if one branch is open, the rest continue to function.

   Disadvantages include the following:

   - When a number of loads are operating in a circuit, the high current drawn from the source can cause the lead-in and lead-out wires to become hot—this could cause a fire.
   - The circuit requires more wire to build.
   - Batteries (cells) don't last as long.

11. Household circuits are all wired in parallel, so each component receives the current independently of the other component.

12. Your chart should be similar to the following one.

Comparing Circuits	
Series Circuits	**Parallel Circuits**
There's only one pathway for the electrons to flow through.	There are two or more branches (pathways) for the electrons to flow through.
The current is the same throughout the entire circuit.	The current is divided between the branches. Equivalent loads (resistances) receive equivalent currents.
Any gap in the circuit shuts off the entire circuit.	The total current (from the source) is equal to the sum of the branch currents. An open branch does not shut off parallel branches.
Loads in the series progressively slow or dim as voltage decreases through the series.	Adding loads draws more current from the battery until the battery reaches its maximum output.

13. Textbook questions 2 and 3 of "Topic 3 Review," page 291:

2. Since $R = \frac{V}{I}$, the ohm relates to a combined unit-volt/ampere.

3. $R = \frac{V}{I}$, where resistance (R) is measured in ohms (Ω), potential difference (V) in volts (V), and current (I) in amperes (A).

Section 1: Lesson 4

Check all the answers in this lesson with your teacher or home instructor.

Section 2: Lesson 1

1. Textbook questions 1 and 2 from "What Did You Find Out?" on page 293:

1. Some possible devices are shown in the table.

Device	Energy Conversion	
	Starting Form	Final Form
hair dryer	electrical	heat
light bulb	electrical	heat and light
stove element	electrical	heat
loudspeaker	electrical	sound
electric motor	electrical	mechanical
electric car	electrical	mechanical
dry cell	chemical	electrical
car battery	chemical	electrical
solar cell	light	electrical
generator	mechanical	electrical
barbecue lighter	mechanical (due to application of pressure while squeezing)	electrical
thermocouple	heat	electrical

2. The conversion of electrical energy to heat is probably the most frequently mentioned conversion. This is because heat is involved to some extent in most energy conversions, and heating devices are very common.

2. The electroplaques are connected in series. The potential differences of all the cells are added to produce the total of 600 V.

3. To function, a thermocouple must be constructed of two dissimilar metals.

4. The thermopile in a thermo-electric generator is composed of a number of thermocouples, which are connected in series to produce a potential difference.

5. Pierre and Jacques Curie were the first people to investigate the link between pressure and electricity.

6. Yes, other materials have been developed that move in response to an electric potential being applied. An example is flexible polymers.

7. Quartz crystals vibrate at a very precise frequency—32 768 times per second—when a potential difference from a cell is applied. This vibration is used to keep time much like the pendulum of a mechanical clock.

8. Light-emitting diodes (LEDs) use semiconductor chips instead of filaments, so they are usually less fragile than conventional light bulbs. LEDs also convert much less energy into heat, so they are energy efficient and not likely to cause a fire.

   Note: A diode is a device that allows current to flow in only one direction—if current flows in the opposite direction it is stopped. Some ammeters and voltmeters are protected by diodes in case they are incorrectly connected into a circuit.

9. Solar cells are photovoltaic cells—they produce electricity from light. Just like dry cells, solar cells have both positive and negative terminals. From there, they can enter and flow through a circuit back to the positive terminal of the solar cell. **Note:** Solar cells consist of two different semiconducting materials fused together. One of the materials used in the cells must have "loose" electrons. When light is absorbed by these materials, the "loose" electrons are freed from the atoms of one of the materials. They migrate into the other material to which the negative terminal is connected.

10. **Textbook questions 2 to 4 from "Topic 4 Review," page 299:**

    2. Thermocouples consist of two different metals wrapped together to form two junctions. When the two junctions are at different temperatures, a potential difference is produced and a current flows.

       Thermocouples are used in both high temperature sensors and thermo-electric generators.

    3. When a piezoelectric crystal is subjected to pressure from sound or percussion (hitting), a potential difference is produced and a small current in the form of a flash of light—or electricity—is given off. Barbecue lighters and crystal microphones use this phenomenon.

       Note: The crystal in microphones encodes sound as an electric current signal.

4. An electric current passing through a piezoelectric crystal causes the crystal's surface to move. Such a motion can be used to adjust electron microscopes. When the motion is a vibration, it can be used to make a watch run accurately.

Section 2: Lesson 2

1. **Textbook questions 1 to 3 from "What Did You Find Out?" on page 300:**

   1. You need two different metal electrodes separated by a conducting solution—an electrolyte—and a closed circuit for the cell to operate.

   2. Answers will vary.

      Factors affecting the voltage produced should include the following:

      - The size (surface area for reaction and ion exchange) and type of metal electrodes should be a factor.
      - In theory, and careful practice, the number of cells should affect the voltage.
      - Smoother surfaces and more pressure increase the contact.
      - Spongier paper towels increase the amount of electrolyte between the electrodes for more conductivity.
      - Contact with the voltmeter probes affect the accuracy of the reading.

   3. You could increase the voltage in these ways:

      - Add more cells to the battery.
      - Use metal electrodes that have smooth surfaces to increase the contact or use only cells composed of the metals that produce the highest readings.
      - You could have a more concentrated or different electrolyte (more free ions).
      - You could increase the temperature of the electrolyte and, therefore, the reaction and transfer rates.

2. An electrochemical cell consists of two electrodes of dissimilar metals immersed in an electrolyte. The electrolyte is a conducting substance—often a solution. The combination of metals and electrolyte chosen affects the rate of reaction and, therefore, the strength of the cell.

3. Aluminum atoms become ions, after having given up electrons to the circuit. The aluminum ions enter the electrolyte solution and move to the copper electrode. Thus, the aluminum strip loses mass and disintegrates. The cell will gradually weaken and "die" as the aluminum gets "used up."

4. The six 1.5 V cells are connected in series to make up a 9 V battery. Due to the single pathway, the electrons must pass through each of the six cells. The electrons gain 1.5 V of energy from each cell.

5. Answers will vary. The hypothesis should address the need for dissimilar materials for the electrodes, the size of the electrodes, and the type of electrolyte.

6. **Textbook questions 1 to 6, 8, and 9 from "Analyze," page 303:**

1. Variables should include the type of electrodes, the surface area of the electrodes, and the type of electrolyte.

2. The responding variable was the voltage and current produced by the wet cell.

3. Bubbles formed on the electrodes.

4. Over time, the voltage and current dropped.

5. **(a)** No bubbles were produced using a salt solution. Halving the surface area produced no visible change in the voltage. Using aluminum and zinc decreased the voltage. Using identical metals produced no observable voltage.

(b) No bubbles were produced using a salt solution. Halving the surface area halved the current produced. Using aluminum and zinc decreased the current. Using identical metals produced no measurable current.

6. **(a)** The potential difference (voltage) was affected by the combination of electrodes and the electrolyte.

(b) The current was affected by the

- running time
- surface area and type of electrodes
- type of electrolyte
- amount of electrode surface area covered by bubbles

8. The largest current was produced when

- the cell was first activated
- using the sulfuric acid electrolyte
- the full length of the electrodes were immersed

9. Copper and zinc produced the greater voltage.

7. **a.** D
   b. B
   c. C
   d. E
   e. A

8. **Textbook questions 1 to 5 from "Evaluate," page 306:**

   1. Three cells in a series—the combined voltage of all three cells—lit the bulb most brightly.

   2. Yes, there is a relationship. The higher the voltage of the battery, the brighter the bulb glows.

   3. **(a)** When cells are arranged in series, the voltage increases by a factor equal to the number of cells. For example, two 1.5 V cells in series yields a battery with 3 V. If this battery is connected to one bulb, the bulb will be brighter than when it's connected to a single cell.

   (b) When cells are arranged in parallel, the voltage across the battery is equal to the voltage of a single cell. For example, two 1.5 V cells in parallel yield a 1.5 V battery. If this battery is connected to one bulb, the bulb will have the same brightness as when it's connected to a single cell. A battery with cells arranged in parallel will last longer than one with the same number of cells in series. Three cells in parallel contain three times more chemicals, so they will last three times longer than a single cell.

   4. The brightness of the bulb is an indication of the amount of current moving through the bulb.

   5. With two cells in series, a potential difference of 3 V was acting (pushing) in one direction. The third cell added in reverse had a potential difference of 1.5 V acting in the opposite direction. That is, $3\text{ V} - 1.5\text{ V} = 1.5\text{ V}$ in the direction of the two cells.

9. **Textbook questions 1 and 3 of "Topic 5 Review," page 307:**

   1. A voltaic cell consists of

   - a negative electrode that provides electrons to the external circuit and positive ions to the electrolyte

   - a positive electrode that receives electrons from the external circuit and positive ions from the electrolyte

   - an electrolyte, which is an ionic solution that conducts electricity

   3. The factors and how they can lead to maximum voltage are as follows:

   - type of electrodes—use two metals that differ most in attraction for electrons
   - type of electrolyte—use strongest acid or base
   - area of electrode—use electrodes with maximum area in contact with electrolyte

Section 2: Lesson 3

Check all the answers in this lesson with your teacher or home instructor.

Section 3: Lesson 1

1. **Textbook questions 1 to 3 from "What Did You Find Out?" on page 309:**

    1. The faster the magnet moves, the faster the needle moves back and forth. The needle also moves farther when the magnet moves faster or farther across more loops of the wire. This indicates that the faster and farther the relative motion, the higher the current produced.

    2. When the coil and magnet are close to each other, more current is produced.

    3. Moving the magnet rapidly inside the coil generates the largest current.

2. **Hint:** Study "Figure 4.34" on page 310 of the textbook. The magnetized piece of soft iron has been polarized. The positive and negative poles of the particles in an unmagnetized piece of soft iron are randomly aligned so their magnetic effects cancel out. *Randomly aligned* means that they are all mixed up—the poles of the individual particles face every possible way.

    In a magnetized piece, the magnetic poles of the individual particles are all aligned in the same direction. The positive ends of the particles all face one direction. Meanwhile, the negative poles face the opposite direction so that the individual fields around each particle combine into one large magnetic field.

3. Faraday introduced words like *ion*, *electrode*, *cathode*, and *anode* to the language of science.

4. You create an electromagnet, which is a magnet created with electricity. The strength of the electromagnet is significantly increased with an added current or voltage. The coil gains polarity, with a magnetic north pole at one end and a magnetic south pole at the other end of the coil.

5. The strength of an electromagnet can be increased by

    - adding an iron or iron alloy core to the coil of wire (concentrates the field lines)
    - increasing the strength of the current (more electrons and/or more energy per electron)
    - adding to the amount of wire in the coil (more electrons)

6. A split ring is used to change the AC from the commutator into DC.

   Note: The split ring reverses contacts with the external circuit during each revolution. This means that although the current in the commutator changes direction, the current in the external circuit always moves in the same direction.

   With a simple generator, the current level moves through a cycle from no current to a maximum current and back to no current with each revolution. These pulses can be smoothed by using many coils mounted in the armature, so that at any one instant at least one coil is producing maximum current. A generator may use 20 or 30 coils to create a fairly constant flow.

7. A generator uses a coil inside a magnet to convert *mechanical* energy into *electrical* energy. A motor uses a coil in a magnet to convert *electrical* energy into *mechanical* energy.

8. In "Figure 4.39(a)," the north pole of the coil is repelled by the north pole of the field magnet at the same time that it is attracted to the south pole of the field magnet. This pushes and pulls the armature in a clockwise rotation.

9. The momentum of the armature carries it past the gap or "dead spot" in the commutator.

10. The split-ring commutator in a simple DC motor reverses the direction of the current through the armature coil. This, in turn, reverses the polarity of the ends of the coil and keeps the coil rotating in the same direction.

11. The stator, a stationary ring surrounding the rotor, takes the place of the field magnet. When current is supplied to the motor, the stator becomes a stationary electromagnet that interacts with the rotor.

    Note: Why, in an AC motor, is an electromagnet used instead of a field magnet? The reason is that AC continually reverses the polarity of the armature. (These reversals are in addition to the reversals due to the split-ring commutator.) Feeding AC into the stator electromagnet cancels out the polarity reversing effect of AC on the armature.

12. **Textbook questions 1 and 2 of "Evaluate" and question 3 from "Extend Your Skills," page 316:**

    1. Answers will vary. But after testing, evaluating, and modifying as appropriate, you will likely reach a high level of success. With the coil rotating for at least 10 s, your score will be 10.

    2. Answers will vary. Problems will centre on the construction and shape of the armature. Other areas of concern are

       - sanding the wire ends to produce a split-ring commutator at one end of the coil
       - balancing the coil in the paper-clip holders
       - the strength or distance from the magnet

3. Troubleshooting instructions could include a number of items.

   Check that

   - you have used a stronger power source and/or a stronger magnet
   - you shaped and balanced the armature carefully
     – The coil is very round, and the leads should come out directly across from each other halfway down the coil.
   - you made the armature support from wire that is stiff enough

13. Textbook questions 1, 3, and 5 of "Topic 6 Review," page 317:

1. Hans Christian Oersted first observed the connection between electricity and magnetism. He made the connection when he observed the reaction of a compass needle to a current-carrying conductor.

3. In an alternating current (AC), electrons move back and forth in a conductor. In a direct current (DC), electrons flow in one direction through the conductor.

   AC is produced by a generator without a split-ring commutator, while DC is usually produced by a battery. DC can also be produced by a generator (dynamo) with a split-ring commutator.

   AC is used in homes because it can be reduced to a safe voltage level—from the high voltage transmission levels—by using transformers.

5. Brushes in motors and generators provide the mobile connection between the external circuit and the spinning commutator of the armature coil. The split-ring commutator allows a current to pass through the brushes in one direction and alternate in the armature coil. Split-ring commutators are used on DC generators and motors.

Section 3: Lesson 2

1. Step-up transformers are used to increase the voltage to be transmitted over the power grid.

2. Circuit breakers trip when a safe level of current is exceeded. A bimetallic strip in the breaker heats up, bends, and opens the circuit. The breaker can be reset after it cools.

   Note: In a fuse the thin wire burns out when current levels go too high. This leaves a permanent gap. The fuse must then be replaced to close the circuit again.

3. **a.** The neutral wire is covered with white insulation. The hot wire is covered with black insulation, while the ground wire is bare copper or covered with green insulation.

   b. The hot wire and the neutral wire carry the current.

   Note: In faulty circuits, some of the electricity may leak into the ground wire.

   Attention: Electricity may also leak out due to human contact providing a path to ground. A ground fault circuit interrupter is a safety device that monitors the electric current into and out of a load. If it detects any leakage, it shuts the circuit down.

4. Each branch circuit is connected in *series* with the metered power supply. The outlets are connected in *parallel* within a branch circuit. The main circuit breaker is connected in *series* with each branch circuit.

5. A microprocessor contains millions of transistors, while an integrated circuit may contain several transistors.

6. **Textbook questions 1 and 3 from "Practice Problems," page 324:**

   1. **Given**

   $V = 120\text{ V}$

   $I = 10\text{ A}$

   Required

   Power, P, in watts (W) and kilowatts (kW)

   Analysis

   Use the expression $P = IV$ to find power.

   Solution

   $$\begin{aligned} P &= IV \\ &= 10\text{ A} \times 120\text{ V} \\ &= 1200\text{ W or } 1.2\text{ kW} \end{aligned}$$

   Paraphrase

   1200 W or 1.2 kW of power is required to operate this hair dryer.

   Note: If you had trouble with problem 1, try problem 2 and compare your answer to the following.

2. **Given**

$$I = 2\text{ A}$$
$$V = 120\text{ V}$$

Required

Power, P, in watts (W)

Analysis

Use the expression $P = IV$ to find power.

Solution

$$\begin{aligned} P &= IV \\ &= 2\text{ A} \times 120\text{ V} \\ &= 240\text{ W} \end{aligned}$$

Paraphrase

The television requires 240 W of power to operate.

3. **Given**

$$P = 900\text{ W}$$
$$I = 7.5\text{ A}$$

Required

Voltage, V, in volts (V)

Analysis

Use the expression $V = \frac{P}{I}$ to find voltage.

Solution

$$\begin{aligned} V &= \frac{P}{I} \\ &= \frac{900\text{ W}}{7.5\text{ A}} \\ &= 120\text{ V} \end{aligned}$$

Paraphrase

The voltage of the circuit to which the microwave is connected is 120 V.

Note: If you had trouble with problem 3, try problem 4 and compare your solution to the following.

4. **Given**

$V = 3\text{ V}$

$I = 0.5\text{ A}$

Required

Maximum power, *P*, in watts (W)

Analysis

Maximum power is reached when maximum voltage is provided. The two cells must be used in series to provide 3 V. Use the expression $P = IV$ to find power.

Solution

$$\begin{aligned} P &= IV \\ &= 0.5\text{ A} \times 3\text{ V} \\ &= 1.5\text{ W} \end{aligned}$$

Paraphrase

The maximum power of this bulb is 1.5 W.

7. Textbook questions 1 and 2 from "Practice Problems," page 325:

1. (a) Given

$P = 700\text{ W or }0.700\text{ kW}$
$t = 30\text{ d}$

Required

The amount of energy required by the refrigerator in a 30-day period

Analysis

Use the expression $E = Pt$ to find energy in kilowatt hours.

Solution

$$\begin{aligned}E &= Pt \\ &= 0.700\text{ kW} \times 30\text{ d} \times 24\text{ h/d} \\ &= 504\text{ kW} \bullet \text{h}\end{aligned}$$

Paraphrase

The refrigerator requires 504 kilowatt hours of electrical energy over a 30-day period.

(b) Given

$E = 504\text{ kW} \bullet \text{h}$
Unit cost 11 cents or $\$0.11/\text{kW} \bullet \text{h}$

Required

The total cost for a 30-day period

Analysis

Use the expression $\text{Cost} = \text{unit cost} \times \text{energy consumption}$.

Solution

$$\begin{aligned}\text{Cost} &= \text{unit cost} \times \text{energy consumption} \\ &= \$0.11/\text{kW} \bullet \text{h} \times 504\text{ kW} \bullet \text{h} \\ &= \$55.44\end{aligned}$$

Paraphrase

Operating the refrigerator costs $55.44 for a 30-day period.

2. (a) Given

$$P = 100\ \text{W} \times 42$$
$$= 4200\ \text{W}$$
$$= 4.2\ \text{kW}$$
$$t = 5\ \text{h}$$

Required

The amount of energy, in kilowatt hours, consumed by the bulbs in a 30-day period

Analysis

Use the expression $E = Pt$ to find energy in kilowatt hours.

Solution

$$E = Pt$$
$$= 4.2\ \text{kW} \times 30\ \text{d} \times 5\ \text{h/d}$$
$$= 630\ \text{kW} \bullet \text{h}$$

Paraphrase

The 42, 100 W bulbs require 630 kilowatt hours of electrical energy over a 30-day period.

(b) Given

$E = 630\ \text{kW} \bullet \text{h}$

Unit cost 11 cents or $\$0.11\ \text{kW} \bullet \text{h}$

Required

The total cost for a 30-day period

Analysis

Use the expression $\text{Cost} = \text{unit cost} \times \text{energy consumption}$.

Solution

$$\text{Cost} = \text{unit cost} \times \text{energy consumption}$$
$$= \$0.11/\text{kW} \bullet \text{h} \times 630\ \text{kW} \bullet \text{h}$$
$$= \$69.30$$

Paraphrase

Operating the bulbs costs $55.44 for a 30-day period.

(c) Given

$$\begin{aligned} P &= 52\ \text{W} \times 42 \\ &= 2184\ \text{W} \\ &= 2.184\ \text{kW} \\ t &= 5\ \text{h} \end{aligned}$$

Required

The savings in a 30-day period if the 100 W bulbs were replaced by 52 W bulbs

Analysis

First, use the expression $E = Pt$ to find energy in kilowatt hours. Then use the expression Savings = unit cost × difference in energy consumption.

Solution

$$\begin{aligned} E &= Pt \\ &= 2.184\ \text{kW} \times 30\ \text{d} \times 5\ \text{h/d} \\ &= 327.6\ \text{kW} \bullet \text{h} \end{aligned}$$

$$\begin{aligned} \text{Savings} &= \text{unit cost} \times \text{difference in energy consumption} \\ &= \$0.11/\text{kW} \bullet \text{h} \times (630\ \text{kW} \bullet \text{h} - 327.6\ \text{kW} \bullet \text{h}) \\ &= \$33.26 \end{aligned}$$

Paraphrase

Using 52 W bulbs in place of 100 W bulbs, \$33.26 would be saved over a 30-day period.

8. The large numbers on an EnerGuide label on an appliance indicate the energy consumption per year in kilowatt hours.

9. Textbook questions 1 and 2 of "Analyze," page 327:

1. Large appliances, such as refrigerators, washers, dryers, and freezers are most likely to be found as big consumers of electrical energy. Reasons would include their large energy requirements, always being on, or having a high rate of use.

Low-level energy consumers would include electronic devices and small appliances. Reasons would be low energy requirements or infrequent use.

2. **(a)** Answers will depend on the actual rate being charged. Suppose \$0.11 is charged for each kilowatt hour.

   For a charge of \$25.00 you receive $\frac{\$25.00}{\$0.11/\text{kW}\bullet\text{h}}$, which equals 227.3 $\text{kW}\bullet\text{h}$. Therefore, to save \$25.00, you must reduce your consumption by 227.3 $\text{kW}\bullet\text{h}$.

   (b) Some ideas are

   - turning lights off when no one is in the room
   - using lower wattage bulbs
   - doing only full loads of dishes and clothes
   - hanging clothes to dry

10. **a.** An incandescent bulb converts about 95% of the electrical energy used into heat. The heat is carried away by air convection and radiated in every direction.

b. In order of their efficiency the lamps are incandescent bulbs, halogen bulbs, and fluorescent tubes.

11. **Textbook questions 1 to 3 from "Practice Problems," page 329:**

The solutions are based on the GRASP method. This is represented by Given, Required, Analysis, Solution, and Paraphrase.

1. **Given**

   $P = 23\ \text{W}$

   $t = 4.0\ \text{h}$

   Useful energy output $= 6.624 \times 10^4\ \text{J}$

   Required

   The efficiency of the fluorescent tube

   Analysis

   Use the expression $E = Pt$ to find energy in joules.

   Use $1\ \text{W} = 1\ \text{J/s}$

   Then, use the expression

   $\text{Efficiency} = \dfrac{\text{useful energy output}}{\text{total energy input}} \times 100\%$ to find efficiency.

Solution

$$
\begin{aligned}
E &= Pt \\
&= 23\ \mathrm{W} \times 4.0\ \mathrm{h} \\
&= 23\ \frac{\mathrm{J}}{\mathrm{s}} \times \left(4.0\ \mathrm{h} \times 60\ \frac{\mathrm{min}}{\mathrm{h}} \times 60\ \frac{\mathrm{s}}{\mathrm{min}}\right) \\
&= 33\,120\ \mathrm{J} \\
&= 331.2\ \mathrm{kJ}
\end{aligned}
$$

$$
\begin{aligned}
\text{Efficiency} &= \frac{\text{useful energy output}}{\text{total energy output}} \times 100\% \\
&= \frac{6.624 \times 10^4\ \mathrm{J}}{3.312 \times 10^5\ \mathrm{J}} \times 100\% \\
&= 20\%
\end{aligned}
$$

Paraphrase

The fluorescent tube is 20% efficient.

2. **Given**

$P = 100 \text{ W}$

$$t = 4.0 \text{ h} \times 3600 \frac{\text{s}}{\text{h}}$$
$$= 14\ 400 \text{ s}$$

Useful energy output $= 6.624 \times 10^4 \text{ J}$

Required

The efficiency of the incandescent bulb

Analysis

Use the expression $E = Pt$ to find energy in joules.

Use $1 \text{ W} = 1 \text{ J/s}$

Then, use the expression

$$\text{Efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$$ to find efficiency.

Solution

$$\begin{aligned} E &= Pt \\ &= 100 \text{ W} \times 4.0 \text{ h} \\ &= 100 \frac{\text{J}}{\text{s}} \times 14\ 400 \text{ s} \\ &= 1\ 440\ 000 \text{ J} \\ &= 1.44 \times 10^6 \text{ J} \end{aligned}$$

$$\begin{aligned} \text{Efficiency} &= \frac{\text{useful energy output}}{\text{total energy input}} \times 100\% \\ &= \frac{6.624 \times 10^4 \text{ J}}{1.44 \times 10^6 \text{ J}} \times 100\% \\ &= 4.6\% \end{aligned}$$

Paraphrase

The incandescent bulb is 4.6% efficient.

Note: For those of you who would like to know how much the fluorescent tubes would save in running costs, do question 3 and compare your solution to the following.

3. **Given**

$E = 1.44 \times 10^6 \frac{\text{J}}{\text{d}}$ for each 100 W bulb

$E = 3.312 \times 105 \frac{\text{J}}{\text{d}}$ for each 23 W bulb

$t = 30 \text{ d}$

unit cost = $0.10 /kW • h

number of bulbs = 25

Required

The savings in a 30-day period if the 100 W bulbs were replaced by 23 W bulbs

Analysis

Use $1 \text{ kW} \bullet \text{h} = 3.6 \times 10^6 \text{ J}$ to convert joules to kilowatt hours.

Then, use the expression Savings = unit cost × difference in energy consumption.

Solution

$$E = \frac{1.44 \times 10^6 \frac{\text{J}}{\text{bulb} \times \text{d}} \times 25 \text{ bulbs} \times 30 \text{ d}}{3.6 \times 10^6 \frac{\text{J}}{\text{kW}\bullet\text{h}}}$$

$$= 300 \text{ kW} \bullet \text{h for 100 W bulbs}$$

$$E = \frac{3.312 \times 10^5 \frac{\text{J}}{\text{bulb} \times \text{d}} \times 25 \text{ bulbs} \times 30 \text{ d}}{3.6 \times 10^6 \frac{\text{J}}{\text{kW}\bullet\text{h}}}$$

$$= 69.0 \text{ kW} \bullet \text{h for 23 W bulbs}$$

$$\begin{aligned} \text{Savings} &= \text{unit cost} \times \text{difference in energy consumption} \\ &= \$0.10 /\text{kW} \bullet \text{h} \times (300 \text{ kW} \bullet \text{h} - 69.0 \text{ kW} \bullet \text{h}) \\ &= \$23.10 \end{aligned}$$

Paraphrase

Using 23 W fluorescent tubes in place of 100 W bulbs would save $23.10 over a 30-day period.

12. Keep in mind the following outdoor electrical dangers:

- Objects are dangerous that are in contact with overhead power lines such as branches, kite strings, ladders, and TV antennas.
- Ungrounded or two-pronged extension cords are potentially dangerous, especially when used outdoors.
- Make sure you locate underground cables before digging.
- Don't use electrical devices in the rain.

13. A current of 0.01 A to 0.025 A causes a person to lose the ability to let go.

Note: The fact that electrical shock causes muscles to contract can also be a lifesaver. If a heart has stopped, a forced contraction of the heart muscle can cause it to resume its normal rhythm.

14. **Textbook questions 2 and 4 of "Topic 7 Review," page 331:**

2. **(a)** $$\begin{aligned} E &= Pt \\ &= (300\ \text{W})(6\ \text{h}) \\ &= 1800\ \text{W} \bullet \text{h} \\ &= 1.800\ \text{kW} \bullet \text{h} \end{aligned}$$

$$\begin{aligned} \text{Cost} &= 1.800\ \text{kWh} \times \$0.11\ \text{h} \\ &= \$0.198 \end{aligned}$$

The cost is approximately \$0.20 or 20 cents.

(b) $$\begin{aligned} E &= Pt \\ &= (300\ \text{W})(300\ \text{h}) \\ &= 90\ 000\ \text{W} \bullet \text{h} \\ &= 90\ \text{kW} \bullet \text{h} \end{aligned}$$

$$\begin{aligned} \text{Cost} &= 90\ \text{kWh} \times \$0.16\ \text{h} \\ &= \$14.40 \end{aligned}$$

The cost is approximately \$14.40.

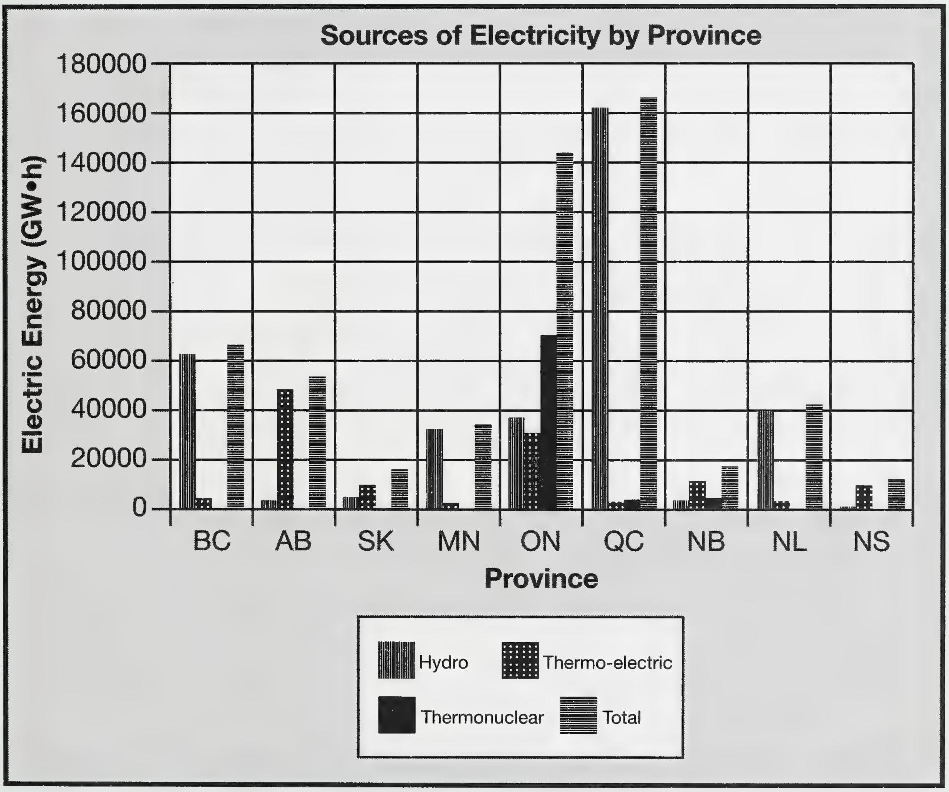
4. Ways to conserve electric energy include

- using bulbs with lower wattage
- turning off the lights when no one is in the room
- switching incandescent bulbs to fluorescent ones

Section 3: Lesson 3

1. **Textbook question "Procedure," page 333:**

The bar graph should have a title and a legend. "Province" should be on the horizontal axis. The vertical axis should be labelled "Electric Energy (GW • h)." See the sample graph obtained using a spreadsheet.



2. **Textbook questions 1 to 3 of "What Did You Find Out?" and questions 4 and 5 from "Extensions," page 333:**

   1. Alberta's electrical energy production is fourth in Canada. This is approximately 11% of the total.

2. Alberta produces most of its electricity in thermo-electric power plants—this is more than in any other province.

3. Canadian sources of electrical energy from highest to lowest are

   - hydroelectric
   - thermo-electric
   - thermonuclear
   - combustion turbine
   - internal combustion

4. Alberta uses thermo-electric plants because it has large quantities of easily accessed, high-grade coal, and few rivers suitable for large hydroelectric plants. B.C. has several large river systems that are suitable for hydroelectric production. Ontario uses hydroelectric, thermonuclear, and thermo-electric power plants because of the availability of river systems, coal, and the technology to support nuclear power plants. Ontario also has a high demand for energy—this increases the need for several sources.

5. Solar, wind, tidal power, biomass burning, and geothermal energy are other sources of electrical production. Their use is limited because solar and wind power are expensive to develop and are dependent on climatic and geographic factors. Tidal power is limited by the availability of suitable locations in Canada, as is geothermal power. Biomass burning may become more popular as fossil fuel prices increase.

3. Biomass is used in some thermo-electric generating plants.

4. Three concerns include the following:

   - Fossil fuel extraction from open-pit mines affects the landscape.
   - Burning fossil fuels causes air pollution and thermal pollution.
   - Fossil fuels are non-renewable.

5. Most sulfur dioxide can be removed with scrubbers. Water solutions, which are sprayed through the waste gases, enter into chemical reactions with the solution.

6. Carbon dioxide is a greenhouse gas. It holds thermal energy in the atmosphere. Higher than normal levels of carbon dioxide in the atmosphere contribute to global warming.

7. **Textbook questions 1 and 2 of "Analyze" and question 3 of "Conclude and Apply," page 335:**

   1. Mining and transporting the coal are the most efficient steps. The least efficient step is the conversion of electrical energy to light in incandescent bulbs.

   2. The overall efficiency of the process is 4%.

3. For mining, use large and more efficient machines. Only mine coal that is easily accessible.

   Transportation efficiency could be aided by using coal that is close to the generating site, and by using more efficient engines to move trains and trucks. Another improvement would be to maintain transportation vehicles to keep them fuel-efficient.

   For generation, operators could use more efficient technologies to maximize the fuel content of the coal, and to reduce heat loss. They could also use larger turbines and generators that are more efficient to reduce resistance in the connectors from the generators to the transformers and the grid.

   For improved transmission, you could use better conductors—superconductors where possible— and transmit at high voltage. Operators could also transmit over shorter distances by using energy plants to provide more localized energy generation.

   Don't use incandescent lights to aid in the conversion to light.

8. Negative effects include the following:

   - Land is flooded to form the reservoirs.
   - The decaying vegetation under the water threatens fish habitat.
   - The dam is an obstacle for migrating fish.
   - The watercourse is changed downstream from the dam.
   - Standing water leaches mercury from the soil.
   - Mercury is biomagnified—this causes problems in the food web.
   - The lake behind the dam gradually fills in with silt and dead plant material.

9. Nuclear power plants are being phased out in Europe because of the difficult problem found in disposing of the radioactive wastes.

10. Nuclear fusion may be environmentally friendly—it does not produce radioactive waste.

11. Cogeneration systems recover waste thermal energy from thermo-electric plants to heat adjacent buildings.

12. An average wind speed of 11 km/h is the minimum required to make large-scale wind farms feasible.

13. Solar cells are not very practical for large-scale power generation due to these reasons:

    - Solar cells are expensive.
    - They are fragile.
    - Solar cells are inefficient (only 15%).
    - In Canada, the least amount of light is available when the need for electricity is at its highest.

14. Heated ground water at geothermal generating sites may contain dissolved sulfur compounds. To prevent these compounds from escaping into the atmosphere, condensed water is pumped back underground.

15. **Textbook questions 1 and 4 of "Topic 8 Review," page 342:**

1. **(a)** Concerns may be the following:

   - Reservoirs flood land and the ecosystems are changed.
   - Flow patterns of rivers are affected.
   - Mercury leaches into the water and affects the food web as it biomagnifies.
   - Fish migration is affected.

   (b) Concerns may include the following:

   - radioactive waste disposal
   - reactor breakdown
   - thermal pollution
   - air pollution

4. Answers will vary. The following is an example.

   Wind and biomass burning are promising sources in Alberta. Southern Alberta has consistent, strong winds. Waste biomass produced by agriculture could replace some fossil fuels.

Section 3: Lesson 4

Check all the answers in this lesson with your teacher or home instructor.

Module Review

Check all the answers in this review with your teacher or home instructor.

Image Credits

Cover
middle right: Corbis
remainder: PhotoDisc Collection/Getty Images

Title Page
PhotoDisc Collection/Getty Images

Contents Pages
Section 1: left: PhotoDisc Collection/Getty Images
right: Rob Van Petten/Digital Vision/Getty Images
Section 3: PhotoDisc Collection/Getty Images

Page
11 **left:** PhotoDisc Collection/Getty Images
right: Rob Van Petten/Digital Vision/Getty Images
12 PhotoDisc Collection/Getty Images
13 PhotoDisc Collection/Getty Images
14 PhotoDisc Collection/Getty Images
15 PhotoDisc Collection/Getty Images
16 **top right:** PhotoDisc Collection/Getty Images
17 PhotoDisc Collection/Getty Images
18 PhotoDisc Collection/Getty Images
19 PhotoDisc Collection/Getty Images
20 PhotoDisc Collection/Getty Images
21 PhotoDisc Collection/Getty Images
22 PhotoDisc Collection/Getty Images
25 PhotoDisc Collection/Getty Images
27 Birch Design Studios
31 © 2003–2004 www.clipart.com
33 PhotoDisc Collection/Getty Images
35 **bowl, spoon, peas:** PhotoDisc Collection/Getty Images
remainder: Digital Vision/Getty Images
36 EyeWire Collection/Getty Images
39 PhotoDisc Collection/Getty Images
41 PhotoDisc Collection/Getty Images
43 PhotoDisc Collection/Getty Images
44 PhotoDisc Collection/Getty Images
46 PhotoDisc Collection/Getty Images
47 PhotoDisc Collection/Getty Images
48 **three head shots:** PhotoDisc Collection/Getty Images
50 **top three:** PhotoDisc Collection/Getty Images
54 PhotoDisc Collection/Getty Images
61 PhotoDisc Collection/Getty Images
63 PhotoDisc Collection/Getty Images
66 **basketball photo:** EyeWire Collection/Getty Images
remainder: PhotoDisc Collection/Getty Images
68 PhotoDisc Collection/Getty Images
69 PhotoDisc Collection/Getty Images